THE

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EDITED FOR THE COUNCIL OF THE AËRONAUTICAL SOCIETY OF GREAT BRITAIN

BY

BERTRAM G. COOPER, A.F.Aë.S.

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Notices of the Aëronautical Society of Great Britain

GENERAL NOTICES

December Elections: Members:—E. C. MIDWINTER, LIEUT. W. PARKE, R.N. (since deceased).

Students:—J. CHALONER, M. CUNHA, G. HORSLEY PORTER, W. F. POTTER.

January Elections: Member:—A. GORDON BOND.
Foreign Member:—E. SURCOUF.

Students:—R. ALSTON, M. DAVIDSON, E. J. LOWE, J. T. MORTON, A. CAMDEN PRATT, T. C. THRUPP.

¶ **Council.** MAJOR F. H. SYKES and MR. W. O. MANNING have been co-opted, under Rule 14, to fill the vacancies on the Council caused by the retirement therefrom of MAJOR A. D. CARDEN and the present Secretary.

¶ **Nominations for the Election of the Council.** The last date for the acceptance of nominations for the Council will be Wednesday, 5th March next. Candidates for election must be nominated by two Voters and no more (see Rules 6-13). Ballot papers will be posted to Voters on 15th March, and must be returned by 12 noon on 25th March, 1913.

¶ **Annual General Meeting.** The Annual General Meeting of the Society will be held on Wednesday, March 26th, at 8 p.m., at the Royal United Service Institution, Whitehall, S.W. (Rule 39).

¶ **Associate Fellowship Election.** Application forms for the next election of Associate Fellows, which will take place in March next, can now be obtained from the Secretary, and it should be noted that it is not necessary that the applicants should be Members of the Society.

Wilbur Wright Memorial Fund.

	£	s.	d.
Amount previously acknowledged	555	3	11
Lieut. Frank P. Lahm	1	0	0
Interest on Aero-Educational Premiums Fund (see below)	0	19	2
Total	£557	3	1

The First Meeting of the Trustees of the above Fund was held at the Offices of the Aeronautical Society, 11, Adam Street, Adelphi, London, W.C., at 4 p.m., on Wednesday, November 13th, 1912, and steps were taken to invest £500 out of the money received.

Mr. Horace Darwin, F.R.S., has accepted the invitation of the Council of the Aeronautical Society to deliver the first Wilbur Wright Memorial Lecture on 21st May next. The subject of the lecture will be announced later.

¶ **Aero-Educational Premiums Fund.** The Council wish to express their grateful thanks to Mr. Griffith Brewer, Mr. John Dunville, Mr. Alec Ogilvie, and Mr. A. Mortimer Singer, for their generosity in constituting the above Fund.

1. The terms of the administration of the Fund are as follows:—

(1) The Fund to remain on deposit at an approved bank and the interest to be paid to the Wilbur Wright Memorial Fund.

(2) The sum of £25 to be paid to every Patent Agent who, being a Member of the Aeronautical Society, becomes an Associate Fellow of the Society.

(3) The further sum of £50 to be paid to every Patent Agent who, being a Member of the Aeronautical Society, becomes a Fellow of the Society.

(4) The sum of £25 to be paid to every Patent Agent who, being a Member of the Royal Aero Club, obtains that Club's aviation or aeronaut certificate.

(5) The further sum of £50 to be paid to every Patent Agent who, being a Member of the Royal Aero Club, obtains that Club's special aviation certificate.

(6) No subscriber to the Fund to be eligible to receive a premium.

(7) In no case must more than two premiums be paid to any one candidate.

(8) At the end of five years, *i.e.*, on the 3rd of September, 1917, the Fund to be closed, and any surplus remaining to be distributed *pro rata* to the subscribers.

¶ **Hardwick Fund.** The Council hope that Members will subscribe to the Fund which has been opened for the widow of their late Fellow Member, Mr. A. Arkell Hardwick. Subscriptions may be sent to the offices of the Society.

¶ **Library.** The Council desires to thank Mr. T. O'B. Hubbard for the gift of a copy of "Description de Montgolfier," by M. Faujas de Saint-Fond, and "The Air Navigated by Man," by William Quartermain.

OBITUARY

LIEUTENANT WILFRED PARKE, R.N.

Lieutenant Wilfred Parke, R.N., who was killed while flying with Mr. A. Arkell Hardwick as passenger, on the 70 H.P. Handley Page monoplane at Wembley on December 15th, was generally recognised as being the most experienced of our naval aviators, as well as one of the best fliers. That he should have met his death in such a simple accident is one of those curious vagaries of fate such as may be the lot of any man. One knows of men who have hunted for years being killed through their horses falling on an ordinary road.

Wilfred Parke was the son of the Reverend A. W. Parke, now Rector of Uplyme, Dorset, and he was born in Devonshire on April 1st, 1889. His early experience of flying was received at Brooklands at the old Avro School, which has given us so many of our finest pilots, among them Howard Pixton, F. R. Raynham, Ronald Kemp, Captain Beattie, and Louis Nöel. Owing to an accident to the Avro School machine he actually took his certificate on a Bristol biplane, the certificate being No. 73, granted on April 25th, 1911, so that he was quite one of the older group of pilots, the men who taught themselves how to fly and were not rushed through their training in a few hours by school instructors.

After taking his certificate he flew on a great variety of machines, but more on the Avro than on any other make, and probably the finest performance in his career was his putting the "enclosed" Avro, with the 60 H.P. Green engine, through the Military Aeroplane Competition during the last few days of the trials, after it had been practically destroyed by an unlucky landing in the first week. In spite of the worst possible weather, and dogged by bad luck, even to the extent of having his climbing test spoiled by a mysterious down-draught, he managed to get through the tests in excellent style.

After the competition he was appointed to the Naval Wing of the Royal Flying Corps, and soon became one of the most generally and genuinely liked members of the corps, for his personal charm won for him the regard of officers and men alike, while his pluck and ability as a flier commanded their respect.

While on week-end leave he regularly journeyed to London to fly any new machine whose maker would allow him to do so, his idea being that the more experience he could acquire the more valuable he would be to the Service. I rather gathered from him that he had a tacit understanding with the authorities that no objection would be raised to his gaining experience in this way so long as his name did not become too prominent in connection with unofficial flights, consequently few people outside the regular frequenters of Hendon and Brooklands knew how much fine flying he did. Also, only a few of his personal friends knew that during the last few weeks of his life he was engaged on special experimental work away from Eastchurch altogether, and that the results of those experiments, which were unfortunately cut short by his death, may have far-reaching results in the future.

While at Eastchurch he flew practically every machine in the place, but his experimental work afterwards was done on a new type Short biplane, with which he achieved excellent results. During the last month or two of his life his week-end flying was done on the Handley Page monoplanes, first on the 50 H.P. and then on the 70 H.P. On both of these he specialised on passenger-carrying, and I have seen him take up over a dozen passengers one after the other during a short December afternoon.

A few months before his death he began to keep a private record of his experiences and impressions of the various machines he had flown, but unhappily he only had time to record the performances of half a dozen machines, though such record as he has left is of very great value indeed.

Personally, Wilfred Parke was one of those fortunate beings who make firm friends wherever they go. His habit of speaking his mind freely, regardless of consequences, might have made enemies for him had it not been for the fact that his opinions had so

much sound judgment behind them that they were in most cases incontrovertible, and the very forcefulness with which he expressed himself removed any sting from his words. His mental activity and strength of character would indubitably have won for him a high place in the King's Service had he been spared, and his death removes a personality which cannot be replaced. C.G.G.

ALFRED ARKELL HARDWICK

Alfred Arkell Hardwick was born in the year 1878 in London, and his career throughout was of a most romantic description. At the age of some fourteen years he went as an apprentice to sea, and sailed several voyages from this country to Australia, South Africa, and Japan—serving altogether three years. On one occasion when rounding Cape Horn he was washed overboard, and was only saved by the returning wave carrying him back on deck again. When he was between seventeen and eighteen he landed in South Africa and there—disappointed in a venture he had undertaken with a friend—joined the Mashonaland Police, serving through the Mashonaland campaign. He gained a medal and bar for this—being mentioned in dispatches. Shortly afterwards we find him in Egypt, where he was employed on the Nile Irrigation Works. There meeting a friend, Mr. George West, he later accompanied him south when the Boer War broke out. The next two or three years find him big-game hunting and exploring in Central Africa, and on his return to England he wrote a book detailing his experiences, entitled: "An Ivory Trader in North Kenia," published by Longmans, Green & Company. As a result of the experience gained he started a Nigerian Trading Company, and went out to West Africa for "The African World" as a special commissioner. Returning from there he went to Morocco with a small party of journalists accompanying Mr. Laurence Harris, of "The Graphic." On his return from Morocco he went to America and was connected with Dr. Spratt, of Coatsville. After a year or so out in the States, Hardwick returned to England and joined Handley Page, Limited, and was with them as Assistant Manager from the early part of 1911 until his death.

Of genial personality, Hardwick had a winning manner that made great friends wherever he went—their circle is world-wide. His keenness for aviation knew no bounds, and he made his work his hobby in every sense of the word. To those who had the pleasure of working with him and of knowing his cheery personality—always helping, always seeking to improve—the loss is indeed a great one. His unfailing belief in the immense future of aviation was such that if he had felt that the sacrifice of his life would in any way have aided the final accomplishment of the mastery of the air, he would willingly have laid it down for so high a purpose. F.H.P.

THE SECOND MEETING of the Forty-eighth Session of the Aëronautical Society of Great Britain was held at the Royal United Service Institution, Whitehall, S.W., on Wednesday, 27th November, 1912, at 8.30 p.m. General Sir James Grierson, K.C.B., C.V.O., presided.

DISCUSSION

AIR TARGETS FOR ARTILLERY AND RIFLE PRACTICE

OPENED BY BRIGADIER-GENERAL F. G. STONE, P.S.C.

HITHERTO we have made very little advance in carrying out artillery and rifle practice against air targets, beyond the familiar attack on a captive balloon. It cannot be considered for a moment that such practice is of very great value as a rehearsal of what would be required from the artillery and infantry in war, when attacking dirigibles or aeroplanes. At the same time it has a certain value which cannot be ignored, inasmuch as it is a training both for artillery and infantry in a wholly different kind of practice to any which they carry out at a land or sea target—different, because no correction for line or elevation can be made as a result of observing the fall of the shot; different also, in respect to the position of gun or rifle, which creates in the case of the gun the necessity for special sighting arrangements, and in the case of the rifle requires a man to accustom himself to shooting at angles of 45° and over. Experiments have also been tried with a target consisting of a large sheet, held up by a flight of kites and towed over a sea range by a cruiser. On the occasion to which I refer, the experiments lacked realism from two causes:—(1) The pace was insufficient to represent that of a dirigible under favourable conditions, and did not approach to that of an aeroplane; (2) the height of the target relatively to that of the guns did not require any extraordinary elevation of the latter, such as would be required under service conditions. As regards (1) I believe that I am correct in saying that the question of pace, with such a target, is by no means an insuperable difficulty, and that 60 miles an hour could be obtained with a little more experience and practice. It is an ascertained fact that a flight of kites will withstand a 60-mile-an-hour wind, and therefore it should be possible to tow them by means of a fast cruiser or destroyer fitted up with suitable winding-in gear. Undoubtedly the resistance offered by a flight of kites with a sheet suspended from them would complicate the problem and perhaps reduce the speed somewhat. As regards (2) the difficulty seems a much more serious one, inasmuch as the towing vessel must be sufficiently far out to sea to secure a safe run for herself in sufficiently deep water, which cannot always be found near the shore, especially if the shore is low lying land, in which case deep water is usually further out than in the vicinity of high land with more or less precipitous cliffs running down to the sea. If the guns have to be perched up on the top of a cliff, one of the principal desiderata is at once discounted in respect to the relative heights of gun and target; and of course the further off the target is, the less will be the angle of sight. It seems scarcely feasible to bring a target of this description into such a position relatively to the guns, as to produce an angle of sight of anything approaching to 45°. There is also another serious limitation to the employment of such a target, and that is the height at which it could be towed. I am not aware that this limit has actually been ascertained by experiment, but it seems safe to hazard the opinion that a height of 3,000 feet would be the maximum; this, with a tow rope 1,000 yards long would give an inclination to the tow line of 45°; actually a steeper inclination at the point of attachment to the target, owing to the necessary sagging of the tow rope by its own weight.

An aeroplane offers such a small target compared with a dirigible, that it would be more satisfactory in this case to use the top kite of the flight as a target; such an arrangement might also with modifications represent a dirigible end on.

But for the reasons given such a target could not conceivably represent the more difficult cases, viz., when the line of sight from the guns is from 45° upwards.

Experiments with an aeroplane as target have recently been carried out at Toulon by the batteries and the Navy in conjunction. The experiments were of importance as the first of their kind, but quite inconclusive. The target, a fair-sized aeroplane, was towed on a steel cable 5,000 ft. long, unwound from an electric drum on the destroyer *Fourche*, driven at full speed across the Bay of Coudoullière. Two batteries opened fire on the target when five miles away. During a quarter of an hour 56 shells were fired, but not a single one hit the mark, though most of them burst near the target. A second trial gave no better results.

The only sort of target which could approximately represent a dirigible or an aeroplane in flight under service conditions would appear to come under one of the following categories :—

(A) A target similar in appearance to a dirigible, towed by a dirigible.

(B) A target similar to an aeroplane, towed by an aeroplane.

(C) An automatic dirigible without anyone on board, controlled, possibly from the ground, by wireless.

(D) An automatic aeroplane similarly controlled.

The most feasible suggestion which I have come across which would conceivably satisfy (A) and (B) is one made by Mr. Alan Owston, of Yokohama. He suggests that the Japanese koi or carp, which are so extensively employed in Japan on gala occasions, flown from high masts, and capable of standing any wind, might be towed by an aeroplane ; these carp, of which I have a specimen here, are inflated by the wind passing through them, and automatically take a horizontal position in flight ; they can be made almost any size. The mouth of the fish has to be sewn to a wooden hoop, which I also have here. To this hoop the towing bridle is made fast, and through this hoop the air rushes when the fish is in flight. I can imagine that the pilots of dirigibles and of aeroplanes might be somewhat shy of running out a tow line from the stern of their machines, consisting of, say, a thousand yards of piano wire ; in the case of an aeroplane it is clear that it would have to be of the type with tractor screw in front, and not with a propeller behind. Presumably the best plan would be to have the target close up to the aeroplane when starting, in fact, to have it actually on board, and let out the wire gradually from a reel. In the case of a dirigible the difficulty might be greater, as the car would have to stand an increased resistance if the attachment were made to the car ; and if the attachment were made to the framework of the gas bag there would be additional complications in respect to the manipulation of the winding reel.

However, considering how many feats are performed to-day by aeroplanes as a matter of course, which would have been scouted as impossible three years ago, we may perhaps be justified in believing that the suggestions here put forward are capable of realisation in no very distant future.

Now as regards (C) and (D) :—There seems to be no insuperable difficulty in constructing either a dirigible or an aeroplane, which would fly on a fairly well defined course under favourable weather conditions, and continue to fly so long as its propellant continued to act. Its control by wireless I also believe to be well within the bounds of possibility, but how such control could be applied is a question for experts, and one with which I would not venture to deal. It is clear that in either case the running of such a target would be costly, and that the acquisition of a safe range either on land or over sea, would be a matter of considerable difficulty. In both cases the partial or total destruction of the target is probable, whether it is hit or not.

An important aspect of this question of air targets for artillery and infantry is that the actual aeroplane presents a far better target when seen from below, than it does when seen from another aeroplane at approximately the same height. During the Army manœuvres, cases constantly occurred of aeroplanes passing each other in the air without being aware that there was another aeroplane in sight. I know one case in which an aeroplane was actually in the air for a total period (not consecutive) of 12 hours, during which several other aeroplanes must have passed it ; both pilot and observer stated that they only saw one machine during the entire period of employment. The reason for this is of course not wholly due to the comparative invisibility of an aeroplane when seen side or end on, though this is the principal reason ; another reason to which some weight attaches is that none of the aeroplanes were fighting machines on the look-

out for victims, but were all reconnoitring machines in which both pilot and observer were intent on watching the ground below them ; and further there is the reason that the time available for observing a hostile aeroplane from another aeroplane is infinitely shorter than is the case from the ground.

I must apologise for the sketchy nature of the paper which I have had the honour of reading to-night, and trust that my audience will regard it merely as opening a discussion from which we may hope to reap some valuable suggestions in a more concrete form, which may give rise to experiments on a more extensive and practical scale than any which have been attempted hitherto.

Lieut.-Col. H. M. Cook : General Stone's lecture has been of special interest to me for several reasons ; firstly, because he was my commanding officer for several years ; secondly, because as a gunner the problem of hitting an aeroplane is one worthy of special study ; and thirdly, because as a pilot, the problem of how not to get hit is one of very considerable importance.

The difficulties of hitting a moving target on the ground are sufficiently great. There are not only the ordinary difficulties of line and range, but the question of speed of the target as well. In the case of an aeroplane, moving in three dimensions, the difficulties increase enormously. I might say they vary not as the square, but as the cube of the factors.

Speaking generally, I should say the most useful gun now in the service for such targets would be the mountain gun. This can be turned rapidly in any direction, while large alterations in elevation can be quickly made.

Let us consider the path of an aeroplane flying low. It may cut the trajectory of a shell in two places. But unless both the shell and the aeroplane were to arrive at either of these two points at the same moment, there would be no hit.

Further, the angle of sight varies every instant with great rapidity. For instance, suppose an approaching aeroplane is flying at 2,700 ft. altitude, the angle of sight varies from roughly 8 degrees at 6,000 yards to 25 degrees at 2,000 yards. Similarly at an altitude of 4,500 feet it would vary from 14 to 41 degrees for the same ranges.

Now if we consider the trajectory again, it will be seen that, at the highest part, it is approximately horizontal. That is to say, for a certain space, errors of range are of little consequence. One may call this space the critical zone for that elevation.

It would seem advantageous to fire at the aeroplane while it is passing through this critical zone. For instance, a battery commander sees an aeroplane approaching. With his rangetakers and instruments he finds the height of the aeroplane. From previously prepared tables he knows what is the critical zone for that particular altitude, and makes his preparations to salute the aeroplane with a rapid burst of fire as it enters the critical zone.

Now it is seen that as the elevation increases the horizontal part of the trajectory, or the critical zone, lies at a greater and greater distance from the gun, so that, speaking as a pilot, it would be advantageous to fly low when at a distance and to mount rapidly as one approaches the guns, until finally when one is vertically above the guns one is in the position of greatest safety. Further, as every projectile must return to the ground, in all probability aeroplanes would only be engaged while approaching from the direction of the enemy.

Col. J. E. Capper, C.B. : Some years ago we tried an " aero-sac," similar in action to the Japanese carp, as a target. There is no difficulty in providing a suitable target if you are prepared to spend enough money. As regards the wireless control of a dirigible, that has been shown to be quite possible, and one has been shown at various music-halls for some time past. For towing targets a motor-boat or hydroplane would probably be able to tow faster than a torpedo boat. It is important to remember that the stronger the wind in which the kite is flying the more vertical does the line become, so that the target would be higher for a given length of line. For example, if the wind were travelling at 45 miles an hour the angle of the line would be about 55°. For land ranges targets could be towed very swiftly from a motor car. I agree that there would be great difficulty in hitting the targets.

Capt. W. A. de C. King : I do not think that there would be any difficulty in getting a flight of kites to an altitude a good deal over 3,000 feet.

The advantage of the "Carp" target is that it offers the same broadside area whatever the angle of elevation may be; but it will be seen that it requires a good deal more material than the "Sheet" target, and is consequently heavier.

As regards towing a target from an aeroplane, should the tow rope be cut by a shell I think the aviator might have a nasty experience. A shell cut the cable of the kites during a practice once.

Might not good use be made of land ranges, a kite target being towed by a specially powerful motor running on rails, portions of the line could be laid running north and south and east and west; these could be connected by a long gentle curve; a kite can be towed round a curve provided the speed is great and the curve is a gentle one; arrangements could be made to raise and lower the target so that variations in height and direction could be obtained during the run.

I would suggest that an experimental target be made of two thin sheets stitched face to face in horizontal and vertical lines about four inches apart, like an eider-down quilt, only that the stuffing would be soot: a shell or bullet passing through one of these 4-inch squares would knock out a certain amount of the soot in it, which I think would be easily noticed by the aid of glasses. I think such a target would be useful in the experimental stages for ascertaining trajectories and testing sights.

Major F. H. Sykes: The two great difficulties in getting aerial targets are that they are expensive and that high speed cannot easily be obtained. The target must travel as fast as the object it represents, and it is not easy to tow it as fast as an aeroplane or dirigible. I have tried running a motor car, imagining that I was towing a target, and have not been able to average more than about 38 miles an hour. An aeroplane could certainly be set so as to fly alone, so that we could use it as a target, but this would be an expensive proceeding, and our stock of aeroplanes is certainly not great at present. I do not think that firing from the ground against aeroplanes will be very effective, and it would be much better, when we get money for experiments, to start these in the air.

Col. H. S. Massy, C.B.: I have listened with great interest to the remarks of General Stone and the other speakers on this important matter. I did not expect to be called upon to speak to-night, but I am glad to say that since General Stone's lecture was announced I have been in communication with some foreign military friends on the subject, and have obtained a few opinions from men interested in the question of terrestrial attack on flying machines. They are almost all of opinion that whatever experiments—necessarily restricted—may be carried out in peace time, the final solution will be found in the attack upon aircraft by fighting machines in the air itself. They are also of opinion that the use of delicate instruments entailing complicated calculations on the battle-field are quite out of place at present, and that a few rough and ready rules which can easily be assimilated by section commanders of cavalry, infantry and machine guns would be far more effective in time of war than the use of any special instruments except, perhaps, a very rapidly acting telemeter or range-finder.

In any case there seems to be a general consensus of opinion that aircraft manœuvring at a height of 2,500 feet and upwards and at a speed of over 50 miles an hour are quite immune from injury except by a chance shot. It is also believed that, notwithstanding the invention of special guns and projectiles, the best shell for such purposes will be the ordinary shrapnel burst just over the flying object.

Colonel Renard, Commandant of one of the French Schools of Musketry, after discussing the merits of various scientific theories and instruments, including a metal sector with pendulum fixed temporarily in the muzzle of a rifle to indicate the angle of approach of aircraft, is finally of opinion that rough and ready methods are best for troops in the field. After instancing the various cases which may present themselves to commanders of small advanced bodies of infantry, cavalry, and machine guns, he sums up as follows:—

As soon as a flying machine is observed, judge its distance rapidly by eye or telemeter, and if the machine is not more than 25° above the horizon (breadth of one hand) sight for the estimated distance less 200 yards and fire for 30 seconds. If the approaching machine is between 25° and 50° (breadth of both hands) sight at the estimated distance less 300 yards. After firing for from 15 to 30 seconds according as the distance has been

either under or above 1,200 yards, sight for 600 yards and continue the fire until the aircraft changes its direction. As the machine goes away fire at it with increased elevations of 300 yards at a time with 15 seconds fire at each elevation. If the machine is crossing the front adopt the same method with increased and decreased elevations of 200 yards each, taking care in all cases to fire at the breadth of half a hand in front of the object aimed at. These rules apply equally to the fire of cavalry, infantry and machine guns. They are very rough, but until experiments can be carried out under service conditions, they are the best available. Colonel Renard also suggests that where large bodies of troops are concerned, the attacking aircraft should be compelled to face two or more distinct barriers of fire, the one carried out as above and the others, preferably with quick-firing guns, directed into the space through which the aircraft must pass, in successive sprays of 30 seconds duration each. But the almost universal opinion is, that at heights of 2,500 feet and upwards, aerial craft on the move are, at the present time, practically immune from terrestrial fire and must be destroyed by similar craft.

LIEUT. WILFRED PARKE, R.N.: It has been suggested that targets might be towed by aeroplanes, but the various speakers seem to have some doubt as to whether this is really practicable.

I beg to take the view that there is no real difficulty at all in towing targets if machines with tractor screws be used.

I was discussing some time ago with Mr. Cody the possibility of effectively attacking ships from aeroplanes, and with his immense experience of aeroplanes and kites he suggested that it would be quite possible to tow a submerged torpedo through the water: now obviously if this can be done, the difficulty of towing a target in air, probably of the Japanese carp type, would be infinitely less. I see no reason why the possible cutting of towing wire by a projectile should have any serious effect on the aeroplane, as it is a matter of common knowledge that the effect of the release of a heavy bomb is practically negligible.

MAJOR B. F. S. BADEN-POWELL: There is one suggestion I might make as regards moving targets. Some of you may remember the experiments that Pilcher made many years ago. He spread out a long line—perhaps 300 or 400 yards—and to the far end of this was attached a tackle—that is to say, the line was rove through blocks in such a way that when one end was drawn along by a horse, the other end of the line, to which the glider was attached, was drawn at a very much more rapid pace. In that way the glider was caused to rise to a considerable height in the air. By similar means a target might be raised and drawn at a rapid speed. The length of the line and the speed limit the duration of time during which the target can be fired on, but it may be sufficient for practice.

Another point is that no mention has been made, I think, of machine guns, especially automatic guns of large calibre, like "pom-poms." These, I believe, are the weapons of offence for use against aircraft. I need hardly explain that the stream of bullets from a machine gun (about 10 per second) may almost be compared to a jet of water from a hose, and it is evident that to play such a stream on a moving aircraft should be more effective than firing a few individual bullets. The opener of the discussion spoke of the vulnerability of aeroplanes, pointing out that only about 1 per cent. of the area of the machine was really vulnerable. But it would be interesting to know what would be the effect on an aeroplane if it were struck about the tip of the wing or tail by an ascending bullet. The balance of the machine might be entirely upset.

BRIGADIER-GENERAL STONE: Colonel Cook gave us some most interesting data in regard to the best method of artillery attack on an aeroplane or dirigible, and at the same time showed how such attack might be evaded; his recommendation that the mountain gun should be used has much to recommend it, but I do not believe in any special form of artillery for this purpose: all that guns can hope to do is to keep the aeroplanes and dirigibles at a respectful height; and any gun, in any part of the field, should be able to take its part in this duty when required. As for a special gun mounted on a motor car to pursue aeroplanes and engage them, I look on such attempts as impracticable.

Colonel Capper brought out a most interesting point with regard to the tow line of a target assuming a steeper inclination in proportion to the speed of the target.

Captain King suggested that the cutting of the tow line between an aeroplane and a target would cause the pilot to have a bad time. I am inclined, on the strength of some of Cody's loading experiments, to doubt this, but would like Mr. Handley Page's opinion. Mr. Handley Page agrees with Captain King, and his opinion is that of an expert.

Captain King's idea of a sort of quilt lined with soot as a target for bullets is one which at once commends itself, and I hope that we may see it tried.

Colonel Massy gives us, as a result of great experience and inquiry, the conclusion that we cannot hope to hit flying machines from the earth: in this I agree, subject to the limitation that the flying machines maintain a suitable altitude. I should deprecate the idea that we are not to practise at such targets because we are unlikely to hit them, for the simple reason that it can only be due to our ability to force them to keep at a respectful distance that we can render their reconnaissance and bomb-throwing a matter of considerable difficulty.

Major Baden-Powell referred to Pilcher's gliding experiments, and considered that a system of tackles arranged on the same principle for getting a flight from a gliding target might be a success. I saw some of Pilcher's experiments myself, and I am afraid that such a system would give us neither the height nor the length of flight necessary for practice shooting.

THE CHAIRMAN: It seems to be the general consensus of opinion that the great difficulty in regard to towed targets is to get the target high enough and fast enough. It seems to be pretty well agreed also that at a height of about 3,000 feet aircraft are practically unhittable. That is to say, if they keep above that height we shall have to fight them from the air, not from the ground. It is very difficult to recognise whether an approaching aeroplane is one of your own or of the enemy. Our own men must not make themselves too conspicuous, and this question of recognising who is coming is a very difficult one. In the manœuvres we have just had the aeroplanes and the dirigibles were a source of comfort and balm to my soul, but I was rather put out one day when a machine came and circled over me as I was having lunch and dropped a message down. I didn't know for the moment whether it was a message, or a missile intended for my destruction. Personally, I think there is no doubt that before land fighting takes place, we shall have to fight and destroy the enemy's aircraft. It seems to me impossible for troops to fight while the hostile aircraft are able to keep up their observation. That is to say, warfare will be impossible unless we have the mastery of the air. As regards automatic targets, these are bound to be very expensive to make and maintain, and it seems to me much better to put one's money into making aircraft able to destroy other aircraft. At the same time, I am sure you will join in a very hearty vote of thanks to General Stone for the very able manner in which he has opened this discussion, and also to those gentlemen who have kindly contributed to it so many interesting and instructive observations.

On the motion of Major Baden-Powell, seconded by Colonel H. S. Massy, C.B., a very hearty vote of thanks was accorded to the Chairman for his kindness in presiding, and the meeting then terminated.

THE THIRD MEETING of the Forty-eighth Session of the Aëronautical Society of Great Britain was held at the Royal United Service Institution, Whitehall, S. W., on Wednesday, 11th December, 1912, at 8.30 p.m. Dr. R. T. Glazebrook, F.R.S., presided.

THE MATHEMATICAL THEORY OF AEROPLANE STABILITY

BY E. H. HARPER, M.A.

I PROPOSE to give some account of the mathematical theory of the stability of an aeroplane moving with constant velocity in a straight line. At the outset it may be stated that almost all the contents of the paper will be found in Professor Bryan's book, *Stability in Aviation*.

The aeroplane will be assumed to possess a vertical plane of symmetry passing through the centre of gravity and the direction of motion. To represent the motion analytically rectangular axes are taken fixed in the aeroplane—the origin at the centre

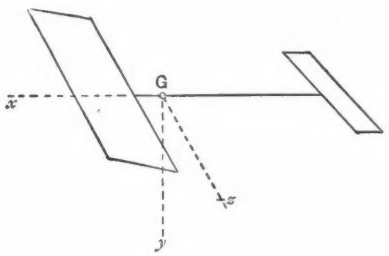


FIG. 1

of gravity, the axis of x in the direction of steady motion, the axis of z at right angles to the plane of symmetry, the axis of y then lies in the plane of symmetry and when the motion is horizontal is vertically downward. U denotes the velocity of steady motion. If the motion is slightly disturbed any possible motion can be represented by the three components, $U+u$, v, w of the velocity of the centre of gravity and angular velocities p, q, r about the axes. The problem before us is to find under what conditions the quantities u, v, w, p, q, r, supposed small, decrease as the aeroplane moves on.

From the assumption of the existence of a plane of symmetry it can be shown that the small quantities w, p, q have no influence on u, v, r and *vice versa*. In other words, the six equations of motion fall into two groups, three of the equations involving u, v, r, and the other three w, p, q. The variations of u, v, r determine the longitudinal or symmetric oscillations of the aeroplane, the variations of w, p, q the asymmetric or lateral oscillations. These two groups of oscillations we shall consider separately.

The equations of steady motion are :—

$$0 = H + W \sin\Theta - X_0$$
$$0 = \quad W \cos\Theta - Y_0$$
$$0 = \quad - Hh - N_0.$$

resolving along the axes of x and y and taking moments about the axis of z,

W is the weight of the aeroplane.

Θ is the angle the axis of x makes with the horizontal, or the downward inclination of the flight-path.

H is the propeller thrust, assumed to act parallel to the axis of x and at a distance h below the centre of gravity.

$-X_o$ and $-Y_o$ are the components of the air pressure along the axes of x and y respectively.

$-N_o$ is the moment of the air pressure about the axis of z.

In the disturbed motion the longitudinal oscillations are got by considering the motion in the plane of symmetry. Resolving and taking moments about the same axes as before and using the equation of steady motion we have, measuring all forces in gravitation units, to the first powers of u, v, r,

$$\frac{W}{g}\frac{du}{dt} = \varepsilon W\cos\Theta - X_u u - X_v v - X_r r$$

$$\frac{W}{g}\left(\frac{dv}{dt} + Ur\right) = -\varepsilon W\sin\Theta - Y_u u - Y_v v - Y_r r$$

$$\frac{W}{g}k^2\frac{dr}{dt} = -N_u u - N_v v - N_r r$$

k is the radius of gyration about the axis of z.

$\Theta + \varepsilon$ is the angle the axis of x makes with the horizontal at any time in the disturbed motion, then since the axis of x is fixed in the aeroplane

$$r = \frac{d\varepsilon}{dt}$$

$-X_u u - X_v v - X_r r$ is the increase in the component of the air pressure along the axis of x over its value in steady motion, and similarly for the corresponding terms in the other two equations.

X_u &c., the coefficients of u, v, r in these expressions, we call the longitudinal derivatives.

H, the propeller thrust, is assumed not to vary.

Assume u, v, ε proportional to $e^{\lambda t}$. Then

$$\frac{du}{dt} = \lambda u,$$

$$\varepsilon = \frac{r}{\lambda} \text{ \&c.}$$

and we have

$$\left(\frac{W}{g}\lambda + X_u\right)u + X_v v + \left(-\frac{W\cos\Theta}{\lambda} + X_r\right)r = 0$$

$$Y_u u + \left(\frac{W}{g}\lambda + Y_v\right)v + \left(\frac{W}{g}U + \frac{W\sin\Theta}{\lambda} + Y_r\right)r = 0$$

$$N_u u \quad N_v v + \left(\frac{W}{g}k^2\lambda + N_r\right)r = 0$$

Eliminate u, v, r from these equations and a biquadratic in λ is obtained. The stability or instability of the motion depends on the nature of the roots of this biquadratic. For stability the real parts of all the roots must be negative. Corresponding to a real negative root $\lambda = -a$, u v, r vary as e^{-at} and so continually diminish. A motion

of this kind we call a subsidence. For an imaginary root with real part negative $\lambda = -a \pm b\sqrt{-1}$. Any one of the quantities u, v, r varies as $e^{-at}\cos(bt+c)$ and the resulting motion is a damped oscillation, the amplitude of the oscillations becoming smaller and smaller. In both cases the stability depends on the real part $-a$ of the root. a is called the modulus of decay or the logarithmic decrement.

Before proceeding further it is necessary to show how the longitudinal derivatives are calculated.

We assume that the air-pressure varies as the square of the velocity. For a plane inclined at a small angle to the line of flight, the air-pressure is assumed to act at right angles to the plane and to vary as the sine of the inclination. These assumptions can also be expressed in the form

air-pressure = K × area × velocity × normal component of velocity.

K is a constant which depends on the form of the plane but difference in the value of K can be allowed for by using, instead of the area of the plane, the *reduced area*, $\frac{K^1}{K}$ × area, where K^1 is the coefficient for the plane.

Our calculations will be limited to narrow planes, planes in which the distance from the entering to the trailing edge is so small in proportion to the area that the shift of the centre of pressure may be neglected. A cambered surface will be supposed replaced by the plane surface which is its nearest equivalent.

Take a single narrow plane at right angles to the plane of symmetry, area S, inclination to axis of x, a, co-ordinates of centre of pressure x, y. Then with our assumptions we find

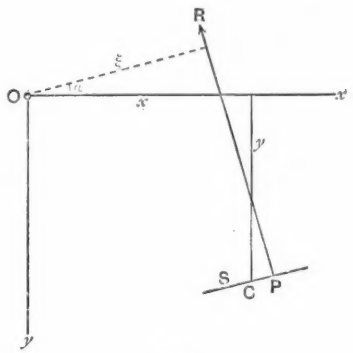


FIG. 2

$$X_o = KU^2S \sin^2 a$$
$$Y_o = KU^2S \sin a \cos a$$
$$N_o = KU^2S \sin a(x\cos a - y \sin a)$$

The longitudinal derivatives for the plane, written in tabular form, are :—

	u	v	r
X	$2KUS\sin^2 a$	$KUS\sin a\cos a$	$KUS\sin a(x\cos a - 2y\sin a)$
Y	$2KUS\sin a\cos a$	$KUS\cos^2 a$	$KUS\cos a(x\cos a - 2y\sin a)$
N	$2KUS\cos a(x\cos a - y\sin a)$	$KUS\cos a(x\cos a - y\sin a)$	$KUS(x\cos a - y\sin a)(x\cos - 2y\sin a)$

Now a is always small in an aeroplane. In general then $y\sin a$ is small compared with $x\cos a$. From an inspection of this table then, we conclude that longitudinal stability depends mainly on the x co-ordinates of the planes, and that an alteration in the height

of a plane has no appreciable influence on the stability unless the alteration is very large. Two superposed surfaces are very nearly equivalent to a single surface whose area is the sum of the areas of the superposed surfaces, and in what follows we assume superposed surfaces replaced by such a single surface.

A portion of the value of the longitudinal derivatives will be due to head-resistance. In X_u this must be taken into account. Call the ratio of the head-resistance to the drift on the planes of the system f; then the part of X_u due to head-resistance is f times the part due to the planes. In the other longitudinal derivatives we neglect the part due to head-resistance as small compared with the effect of the planes.

The simplest possible case of longitudinal stability is that of an aeroplane with a single supporting surface and a neutral horizontal tail plane—using the word "neutral"

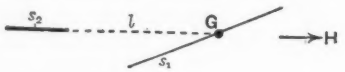


FIG. 3

for a plane parallel to the line of flight. The propeller thrust we assume to act through the centre of gravity and the centre of pressure of the supporting plane to coincide with the centre of gravity.

S is the area of the main plane;
α its inclination;
Write S^1 for $S\cos^2\alpha$ and μ for $\tan\alpha$;
σ is the area of the tail plane;
l its distance behind the centre of gravity.

The longitudinal derivatives are:—

	u	v	r
X	$2KUS^{12}(1+f)$	$KUS^1\mu$	0
Y	$2KUS^1\mu$	$KU(S+\sigma)$	$-KU\sigma l$
N	0	$-KU\sigma l$	$\cdot KU\sigma l^2$

Substituting these values the coefficients of the biquadratic in λ can be calculated. Since μ ($\tan\alpha$) is small the approximate values of the roots to the lowest power of μ involved can be readily found. Two of the roots are large compared with the other two, the two larger roots determining the short oscillation and the two smaller ones the long oscillation.

Using the equation of steady motion

$$W\cos\Theta = KU^2S^1\mu$$

and introducing the symbol d to represent

$$\frac{W}{KgS^1}\left(=\frac{U^2\mu}{g\cos\Theta}\right)$$

the two larger values of λ are given by

$$\left(\frac{U\lambda}{g\cos\Theta}\mu\right)^2 S^1k^2+\frac{U\lambda}{g\cos\Theta}\mu(S^1k^2+\sigma k^2+\sigma l^2)+\sigma l(l+d)=0$$

The real parts of the roots are negative if all the coefficients have the same sign, so the motion is stable so far as the short oscillations are concerned if l and $l+d$ are both positive or both negative. The short oscillation consists of a damped oscillation or of two subsidences according as the roots are imaginary or real.

The two smaller values of λ are to a first approximation given by

$$\left(\frac{U\lambda}{g\cos\Theta}\right)^2 (l+d)+2d=0$$

For stability $l+d$ must be positive. Combining this with the condition found from the short oscillations l must be positive or the neutral tail must be behind. This is otherwise evident from the consideration that the aeroplane when tilted must be righted by the air-pressure on the tail. The value of λ obtained is purely imaginary and determines the period of the long oscillation.

To find the modulus of decay λ^1 the approximation must be carried to a higher power of μ and in this way we find

$$\frac{U\lambda^1}{g\cos\Theta} = \left[f+\sqrt{\frac{1-\frac{k^2}{ld}\frac{S^1+\sigma}{\sigma}}{\left(1+\frac{l}{d}\right)^2}} \right] + \frac{d}{l+d}\frac{\tan\Theta}{2}$$

For stability the value of λ^1 must be positive. The two conditions for stability then are :—

(1) The neutral tail must be behind ;
(2) λ^1 must be positive.

The modulus of decay of the short oscillation, being of the order $\frac{1}{\mu}$, is much larger than the modulus of decay of the long oscillation which is of order μ. The degree of stability obtained depends then on the value of λ^1 and an examination of this value is of importance.

The expression for λ^1 given above may be supposed to consist of three parts. The first part :

$$\frac{g\cos\Theta}{U}\mu f$$

is due to head resistance. Increased head-resistance then gives increased stability, but of course would involve increased propeller thrust.

The second part :

$$\frac{g\cos\Theta\mu}{U}\,\frac{1-\frac{k^2}{ld}\frac{S^1+\sigma}{\sigma}}{\left(1+\frac{l}{d}\right)^2}$$

depends on the position of the tail plane. It can be made greater by diminishing k and by increasing d and σ.

d being equal to $\frac{W}{KgS^1}$ or $\frac{U^2}{g\cos\Theta}\mu$ may be increased by increasing either the velocity or the inclination of the main plane. Obviously increasing the velocity is the better method.

The stability is a maximum when the tail plane is so placed that

$$l = \frac{3k^2\frac{S^1+\sigma}{\sigma} + \sqrt{k^2\frac{S^1+\sigma}{\sigma}\left[9k^2\frac{S^1+\sigma}{\sigma} + 8d^2\right]}}{4d}$$

To make the stability approach the maximum possible $k^2\frac{S^1+\sigma}{\sigma}$ should be made small compared with d^2 and then the best position of the tail plane is approximately given by

$$l = \sqrt{\frac{k^2}{2}\frac{S^1+\sigma}{\sigma}}$$

The third part of λ^1

$$\frac{\frac{g}{2U}}{\frac{\sin\Theta}{1+\frac{l}{d}}}$$

depends on the inclination of the line of flight. The stability is increased when the aeroplane is descending, diminished when it is ascending. The motion becomes unstable at an angle of ascent given by

$$\frac{-\tan\Theta}{2\mu} = f\left(1+\frac{l}{d}\right) + \frac{1-\frac{k^2}{ld}\frac{S^1+\sigma}{\sigma}}{1+\frac{l}{d}}$$

Increased stability in ascending flight could be gained in two ways. First by increasing the ratio of l to d, which would involve a sacrifice of some stability in horizontal flight; or, secondly, by raising the propeller so that its thrust acts above the centre of gravity.

The foregoing formulæ can be applied to a system of any number of narrow planes, the centres of pressure of the planes, the centre of gravity, and the line of action of the

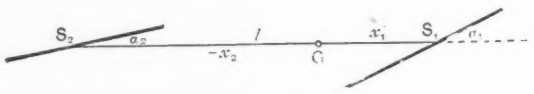


FIG. 4

propeller thrust being supposed at the same height. We can in fact find a system of a single lifting plane and a neutral tail equivalent in every respect to the multiple plane system. Equating the longitudinal derivatives of the two systems the equations to be solved are :—

$$
\begin{aligned}
S^1\mu^2(1+f) &= \Sigma S_1 \sin^2\alpha_1 + X^1{}_u/KU \\
S^1\mu &= \Sigma S_1 \sin\alpha_1 \cos\alpha_1 \\
S^1 + \sigma &= \Sigma S_1 \cos^2\alpha_1 \\
-\sigma l &= \Sigma S_1 x_1 \cos^2\alpha_1 \\
\sigma l^2 &= \Sigma S_1 x_1{}^2 \cos^2\alpha_1
\end{aligned}
$$

Where the left-hand side applies to the single lifting system, and the right-hand side to the multiple lifting system. $X^1{}_u$ is the part of X_u due to head-resistance.

For a system of two lifting planes it can be shown that the head-resistance remains the same in the equivalent system. The condition that the neutral tail should be behind is equivalent to the condition that the front plane in the two-plane system should have a greater inclination than the rear one.

The head-resistance in the equivalent single lifting system is in general greater than that of a system of more than two planes. Any advantage there is in using more than two planes could equally well be gained by increasing the head-resistance of a two-plane system and is open to the same objection.

So far we have only taken into account those factors of the problem which seem to be of greatest importance. Corrections may afterwards be introduced by taking into account the neglected factors. In Professor Bryan's book the effect of variations in the propeller-thrust, of raising or lowering the planes or the propeller, of shifting of the centre of pressure and of cambered surfaces are all discussed. In a practicable aeroplane all these corrections are probably small.

Lateral Stability

The problem of lateral stability is much more difficult to solve than that of longitudinal stability. The equations governing the lateral oscillations involve w, the sidewise velocity, p the angular velocity of rolling or canting, and q the angular velocity of veering. The fact that both p and q appear in these equations shows that lateral and directional stability are given by the same conditions. Complete directional stability, however, cannot be secured. If the aeroplane has turned about a vertical axis so that its head points in a different direction, all the forces remain unchanged relative to the aeroplane and there cannot be any force tending to turn it back. It is easy to see that lateral stability can only be gained by utilising the sidewise motion. If the aeroplane has taken

Fig. 5

up a canted position, the air-pressure changes its direction so as to maintain the same position relative to the aeroplane. Neither the weight nor the air-pressure can tend to right the aeroplane. The combined result of the two is to produce a sideways motion, and it is only by this motion that a righting force can be brought into play.

The equations of motion for the lateral oscillations are :—

$$\frac{W}{g}\left(\frac{dw}{dt} - qU\right) = -W\phi\cos\Theta + W\psi\sin\Theta - wZ_w - pZ_p - qZ_q$$

$$\frac{A}{g}\frac{dp}{dt} - \frac{F}{g}\frac{dq}{dt} = -wL_w - pL_p - qL_q$$

$$\frac{B}{g}\frac{dq}{dt} - \frac{F}{g}\frac{dp}{dt} = -wM_w - pM_p - qM_q$$

The meanings of W, g, U, w, p, q have been explained before.

ϕ is the small angle through which the aeroplane has turned about the axis of x, or the angle of cant.

$$\text{Then } p = \frac{d\phi}{dt}$$

ψ is the small angle through which the aeroplane has turned about the axis of y.

$$\text{Then } q = \frac{d\psi}{dt}$$

A and B are the moments of inertia about the axes of x and y respectively.

F is the product of inertia $\int xydm$.

$-wZ_w - pZ_p - qZ_q$ is the component of the air-pressure perpendicular to the plane of symmetry.

$-wL_w - pL_p - qL_q$ is the moment of the air-pressure about the axis of x.

$-wM_w - pM_p - qM_q$ is the corresponding moment about the axis of y.

Z_w, &c., the coefficients of w, p, q in these expressions, we call the lateral derivatives.

As before, assume ϕ, ψ, w proportional to $e^{\lambda t}$ and we have

$$\left(\frac{W\lambda}{g} + Z_w\right)w + \left(\frac{W}{\lambda}\cos\Theta + Z_p\right)p + \left(-\frac{WU}{g} - \frac{W}{\lambda}\sin\Theta + Z_q\right)q = 0$$

$$L_w\, w + \left(\frac{A}{g}\lambda + L_p\right)p + \left(-\frac{F}{\lambda} + L_q\right)q = 0$$

$$M_w\, w + \left(-\frac{F}{g}\lambda + M_p\right)p + \left(\frac{B}{g}\lambda + M_q\right)q = 0$$

Eliminate w, p, q and we get a biquadratic for λ. The condition for lateral stability as before is that the real parts of all the roots of this equation should be negative. These roots cannot be found approximately as readily as the corresponding roots in the equation of longitudinal stability.

If the biquadratic is written,

$$\mathfrak{A}\lambda^4 + \mathfrak{B}\lambda^3 + \mathfrak{C}\lambda^2 + \mathfrak{D}\lambda + \mathfrak{E} = 0.$$

the real parts of all the roots are negative if

$$\mathfrak{A}, \mathfrak{B}, \mathfrak{C}, \mathfrak{D}, \mathfrak{E} \;\&\; \mathfrak{B}\mathfrak{C}\mathfrak{D} - \mathfrak{A}\mathfrak{D}^2 - \mathfrak{E}\mathfrak{B}^2.$$

are all positive or all negative.

The method of working is first to calculate the lateral derivatives Z_w &c., then the coefficients $\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$, $\mathfrak{D}$, $\mathfrak{E}$ of the biquadratic and the quantity $\mathfrak{BCD}-\mathfrak{AD}^2-\mathfrak{EB}^2$.

To calculate the lateral derivatives we assume as before that we are only dealing with narrow planes, that the air-pressure acts at right angles to the plane and obeys the sine law. For long planes we also assume that the air-pressure on each portion can be calculated independently in accordance with these assumptions. The lateral derivatives vary very much with the nature of the plane.

For a straight plane, that is, one perpendicular to the plane of symmetry, the lateral derivatives are :—

	w	p	q
Z	0	0	0
L	0	$KUI\cos^2\alpha$	$-2KUI\cos\alpha\sin\alpha$
M	0	$-KUI\cos\alpha\sin\alpha$	$2KUI\sin^2\alpha$

where I is the moment $\int z^2 dS$ of the area of the plane with respect to the plane of symmetry,

α is the inclination of the plane.

The effect, therefore, of a straight plane depends altogether on its dimensions perpendicular to the plane of symmetry. For a single straight plane all but the first two of the coefficients of the biquadratic vanish. For any number of straight planes the last two coefficients vanish, whence straight planes alone cannot give stability. In fact we see that they cannot damp out a velocity perpendicular to the plane of symmetry nor right a cant.

That a cant can only be righted by the sideways motion suggests the use of planes parallel to the plane of symmetry. Such planes we call fins. For a small fin, area T the lateral derivatives are :—

	w	p	q
Z	KUT	KUyT	$-KUxT$
L	KUyT	KUy^2T	$-KUxyT$
M	$-KUxT$	$-KUxyT$	KUx^2T

The effect of a fin, then, is independent of its distance from the plane of symmetry, and a number of fins placed side by side are equivalent to a single fin placed in the plane of symmetry.

With a straight plane and a single fin two of the conditions of stability require the

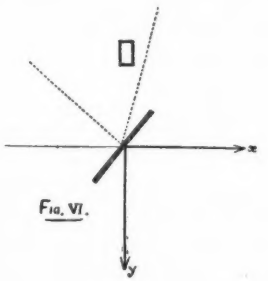


FIG. 6

fin to be placed in the angle between two lines passing through the centre of gravity, so as to make both

$$x\cos\alpha - y\sin\alpha$$

and $$-KU^2I\cos\alpha(x\cos\alpha - y\sin\alpha) - By$$

positive. The third condition of stability is complicated and more difficult to obtain. The motion becomes unstable when the angle of descent is greater than $\tan^{-1}(2\tan\alpha)$. Much better stability is obtained by the use of two fins.

For a number of fins the derivatives can be transformed by the methods applicable to centres of gravity and moments of inertia. Call the total area of all the fins T, the co-ordinates of their centre of pressure (x, y) and M_1, M_2, P their moments and product of inertia with respect to axes parallel to the principal axes through this point—then we have :—

	w	p	q
Z	KUT	$KUyT$	$-KUxT$
L	KUyT	$KU(y^2T+M_1)$	$-KU(xyT+P)$
M	$-KUxT$	$-KU(xyT+P)$	$-KU(x^2T+M_2)$

Professor Bryan has shown that the effect of M_2 is very important in maintaining lateral stability. With a single straight plane try the effect of two fins, one in front and one behind the aeroplane. At first let their centre of pressure coincide with the centre of gravity. These two fins with the supporting plane will damp rolling, veering and sidewise motion but still no force righting a cant is introduced. To this corresponds

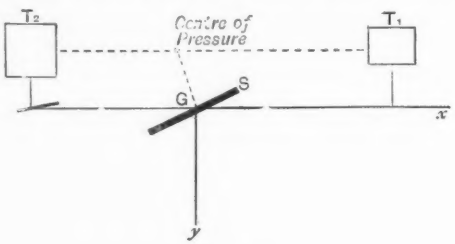


FIG. 7

the fact that the last coefficient $\mathfrak{E}$ of the biquadratic vanishes. To make $\mathfrak{E}$ positive we may raise the fins so that the centre of pressure is above the centre of gravity. Stability will be secured if the centre of pressure is not raised too high. We find that if this height exceeds a certain value,

$$\mathfrak{BCD}-\mathfrak{AD}^2-\mathfrak{EB}^2$$

changes sign which points out that oscillations of increasing amplitude are set up. Professor Bryan finds that stability is obtained if the height is not more than

$$\frac{K^2U^2gI^2\cos^4\alpha}{W\cdot A\cdot}$$

The stability obtained in this way is very little affected by the inclination of the flight path to the horizontal.

Stability might also be secured by moving the fins forward so that the centre of pressure is in front of the centre of gravity. If the centre of pressure is too far forward

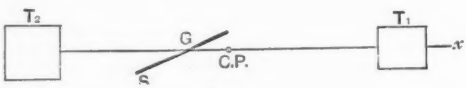


FIG. 8

oscillations of increasing amplitude are set up. The motion becomes unstable when the angle of descent is greater than $tan^{-1}(2tan\alpha)$.

Another disposition of the fins that has been worked out is one fin behind and one above the centre of gravity. With these the distance of the tail fin behind the centre

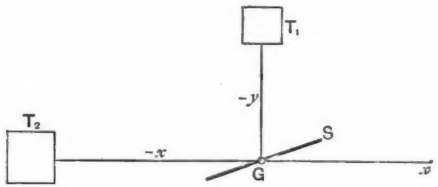


FIG. 9

of gravity must not be less than a certain inferior limit. The motion becomes unstable in ascending at more than a certain inclination.

Neutral planes, that is planes parallel to the line of flight which experience no air-pressure in steady motion, have the same effect on lateral stability as fins. The equivalent fin is placed where a perpendicular to the neutral plane through its centre of pressure

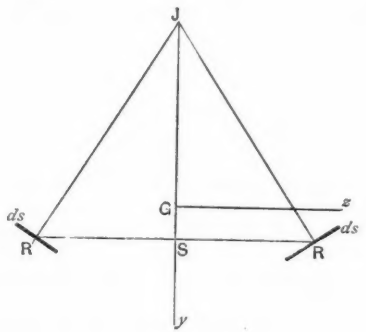


FIG. 10

meets the plane of symmetry. For example, if the two halves of a neutral horizontal tail are bent upwards at a dihedral angle they have the same effect as a fin placed above the tail. Constructional reasons determine whether neutral planes or fins are used.

Planes that are neither straight nor neutral have a more complicated effect. A pair of small planes symmetrically placed on each side of the plane of symmetry may be called stabilisers. The effect of a pair of stabilisers is partially equivalent to that of a fin placed as before where the perpendiculars to the stabilisers at their centres of pressure meet the plane of symmetry. If the stabilisers have a positive inclination to the line of flight they are in front of this equivalent fin, if a negative inclination behind it. The stabilisers have also an additional effect on lateral stability depending on their distance behind or in front of the equivalent fin. For a straight plane with a pair of stabilisers the equivalent fin must satisfy the two conditions we have mentioned when discussing a single fin. The two corresponding coefficients of the biquadratic in fact are independent of the distance of the stabilisers behind or in front of the fin. The further behind the stabilisers are the greater the damping effect and the third condition which we mentioned as being complicated for a single fin can be satisfied if the stabilisers can be placed sufficiently far back. Of course as they are moved back their negative inclination must increase if the equivalent fin remains in the same position. Such stabilising planes may be attached to aeroplane wing tips.

We next consider bent-up wings such as are used on many aeroplanes. Their effect is similar to that of a fin placed above the wings. The bent-up wings alone may under certain circumstances produce lateral stability. When the horizontal tail is

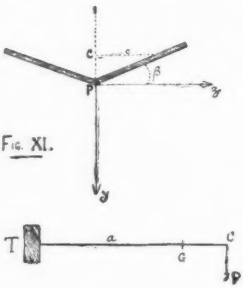


FIG. XI.

FIG. 11

non-lifting and the propeller-thrust acts through the centre of gravity, the line of action of the resultant air-pressure on the wings must also pass through the centre of gravity. Such an aeroplane is laterally unstable. To make it stable the centre of gravity must be moved back a certain distance, d, behind the centre of pressure of the wings, so that

$$d > c \tan \alpha \sin \beta$$

c is the distance of the centre of pressure of one of the wings from the plane of symmetry.

α is the inclination of the wings to the line of flight.

β is the inclination of the wings to a perpendicular to the plane of symmetry.

Of course, to preserve the balance the tail must be given a certain amount of lift or the propeller raised above the centre of gravity. If d is too great oscillations of increasing amplitude are set up. The motion becomes unstable if the aeroplane is descending at an angle greater than twice the inclination of the wings to the line of flight.

Stability can also be obtained if the centre of gravity coincides with the centre of pressure of the wings by using a tail fin. The fin must be placed at a distance behind the centre of gravity a so that

$$a > \frac{2\tan\alpha}{\sin\beta} \frac{c^2+R^2}{c}$$

where R is radius of gyration of the area of one of the wings about its centre of pressure.

The stability in this case falls off as the aeroplane ascends.

By combining the two methods, adjusting the position and area of the tail fin, and the position of the centre of gravity, the stability can be made approximately independent of the inclination of the flight path. The condition to be satisfied is

$$Ta = (d - c \tan \alpha \sin \beta) \frac{R^2}{R^2 + c^2 \cos^2\beta} S \sin^2\beta \cos^2\alpha$$

where T is the area of the tail fin.

Two of the methods of obtaining lateral stability investigated seem much more satisfactory than the others. The first of these is the system with two fins at the same height above the centre of gravity, the second the system of bent-up wings with a tail fin. In both cases the system can be adjusted so that the stability is little affected by the inclination of the flight path. In the other systems considered the stability vanishes in either ascending or descending flight when the inclination of the flight path to the horizontal is too great.

The Council are indebted to the courtesy of Messrs. Macmillan and Company, Limited, for the loan of the blocks illustrating this paper.

An investigation not yet published shows that lateral stability which is unaffected by the inclination of the flight path and with the lateral oscillations unaccompanied by directional oscillations can be obtained. With two fins for example, one in front and one behind, these results could be gained by making the front fin the higher. Professor Bryan's result as to the position and height of the centre of pressure of the fins remains unaltered.

The assumptions made in calculating the lateral derivatives are, of course, not strictly in accordance with the facts. Professor Bryan discusses the corrections to be introduced for friction, camber of surfaces, effects at the ends of long planes, and also the influence of head-resistance on lateral stability ; but lack of time prevents me from giving an account of these corrections.

Discussion

The Chairman : Before asking for your remarks on the paper which Mr. Harper has just read I may perhaps be permitted to say a few words on this subject of the stability of the aeroplane, which is undoubtedly of the first importance. Some of you may perhaps have been inclined to think this evening that though the art of flying may be difficult, the mathematical theory of flight is more difficult still. We are much indebted both to Mr. Lanchester, whose earlier work on the subject is well known, and to Professor Bryan and Mr. Harper, for the clear way in which they have dealt with this complicated and difficult matter, and have set before us the main principles of the theory of aeroplane stability. It has been shown that, to a first approximation at least, the problem of longitudinal stability, relating to the motion of an aeroplane parallel to its vertical plane of symmetry, may be treated separately from that of lateral or asymmetric stability, in which we are concerned with the veering or rolling motions of the machine. As regards longitudinal stability, Professor Bryan and Mr. Harper have shown that the motion of an aeroplane disturbed from its condition of steady flight is characterised by two types of oscillation, one a slow oscillation consisting in an undulatory movement of the centre of gravity, the other a quick oscillation super-imposed on the former, independent of the variations of the velocity in the line of flight, but determined by the motion at right angles to that line, and by the rotation of the machine about its centre of gravity. In practice it is the slow oscillations which are of the greater importance, and, on certain assumptions, Professor Bryan has shown under what conditions the motion will be stable so far as these slow oscillations are concerned.

Similarly the problem of lateral stability has been attacked. It has been shown that the motions of veering and rolling are interdependent, and the methods of analysis employed lead to certain conclusions as to ways in which the lateral stability of an aeroplane in still air can be secured.

In speaking of longitudinal stability, I have said that Professor Bryan's calculations are based on certain assumptions, on certain data. It is at this point that the chief difficulty arises at present in formulating a mathematical theory of aeroplane stability ; only some of the data necessary as a basis for the calculations have yet been determined by experiment. Professor Bryan makes use of certain values for what I may call the " constants " of an aeroplane, which he has chosen to the best advantage from the experimental results available ; but he points out that there are other quantities of importance for which he has no data, and therefore he is not able properly to take them into account. The determination of these data is the work that it is most necessary at the moment should be done to enable the question of stability to be fully investigated. As many of you are aware, this is a matter to which the Advisory Committee for Aeronautics are giving special attention and we hope that the experiments now in progress at the National Physical Laboratory may lead to fuller and clearer knowledge on this very important branch of the science of aeronautics.

It has been urged recently by many qualified to express an opinion that it is by no means clear that a high degree of stability is a desirable quality in an aeroplane. Thus

a machine which is stable when the air is still may in a gusty wind have too great a tendency to turn to face the gusts, and so maintain a perpetual oscillation which is trying to the flier. I do not propose this evening to attempt any discussion of this aspect of the question, but I wish to point out that the possibility that this view may be correct makes it not less, but more necessary, that all the data needed to enable the motion of an aeroplane to be fully investigated, both mathematically and by experiment, should be available. If only a slight degree of stability, an approach to neutral equilibrium, is what is desirable, the designer must know the modifications necessary to attain the condition ; and we must be able to say how a machine so designed will behave under the varied circumstances which may arise in actual flight. The work of Mr. Harper and of Professor Bryan is of great assistance both in showing us how to use to the best advantage the information we already have, and in indicating some at least of the directions to be followed in making future progress.

Sir George Greenhill : It is a great responsibility, sir, with so many real flying men in the room, to open a discussion on the stability of a flying machine, treated as a dynamical question.

We take a gallop through the equations, and then walking back to the starting post we have to concentrate attention on the assumptions introduced at the outset, because a mathematical argument will not bring out more than has been put in at the start.

Huxley considered this a great defect in mathematics, but all we can claim is to have re-fashioned the facts, and shown the logical consequence.

We do not reproach the builder of a modern steamer because there is no more steel, much less, than was dug out of the ground. But the shipbuilder has remodelled the crude ore into a shape useful to mankind.

This subject of stability has long been the study of Professor Bryan, and Mr. Harper has given us here the essence of his mathematical treatment.

Professor Bryan was a firm believer in the possibility of Mechanical Flight, long before the petrol motor had made it feasible. We find now that with unlimited power at disposal, the speed attainable has solved the stability question automatically.

But later, when we desire more flexibility in speed, with a considerable range from high to low, and even to hovering, Professor Bryan will prove the utility of his mathematics.

The great problem at first was to get up into the air somehow and come down again without a smash, using the atmosphere as the experimental laboratory.

Great power and speed was wanted.

Now this main question is settled, a return can be made to the theory.

Here I must confess it alarms me to see so complicated a question treated in a manner quite elementary, because a simple experiment reveals much more complexity—a plate sinking in water or the evolutions of a card dropped in the air.

The initial assumption of the paper is not verified, that w, p, q, have no influence on u, v, r, especially with gyroscopic influence.

If we go deeper it opens up a large question. The gyroscopic effects have not been considered in the equations ; these are considerable, in assuring the stability of q, r—not of p—with a single motor and screw.

The novice was warned against a turn to the right with a Gnome engine and left-handed propeller. Putting the helm of the vertical rudder to starboard to turn to the left will make the machine turn down, and get up speed. But helm to port makes the machine rear and buck, the way is checked, and down the machine will soon come like a stone. With more experience the steering can be effected with the horizontal rudder. So to steer to the right—put the helm *up*, literally, to make the machine descend. But now gyroscopic influence makes it turn to the right, without any alarming sensation of bucking and rearing. Rankine, the engineers' mathematician, gave in his inaugural address the two points of view, of the practical engineer and the theoretical mathematician.

The question for the engineer is—What am I to do ? And he must act at once, on whatever theory he can command, checked by his practical experience. But for the theorist the question is : What am I to *think?* And he can take his time over it in his study to an unlimited extent, without any hurry.

We shall reap the benefit of Professor Bryan's careful analysis, as Mr. Harper has given it to us this evening, when the physical facts and numerical data are better known on which theory must be founded, and these facts can be obtained only up in the air.

The pioneer of flight had to get up into the air somehow (he could not wait for the solution of a differential equation or its determinantal quartic) and chance some risk of his friends being called by the theorist—"Assassin."

PROFESSOR M. J. M. HILL, of University College, London, on being asked by the Chairman whether he had any remarks to make as a theoretical mathematician on the subject of the paper, said that he was much interested in one of the formulæ it contained, viz. :—

$$l = \sqrt{\frac{k^2}{2} \cdot \frac{S' + \sigma}{\sigma}}$$

In a glider, built by his son for the purpose of studying questions of stability, S' was approximately 7σ, and k approximately two feet. This would give for l an approximate value of four feet. In his son's glider, however, l was about 11 feet, and he would therefore be glad to know whether any experiments had been made by Professor Bryan and Mr. Harper for the purpose of deciding whether the values given by the formula for l accord with the results of experiment.

COLONEL FULLERTON, R.E. : There are a few points on which I should like the lecturer to give us some further information.

Variation in the Propeller Thrust.—The lecturer has omitted this (probably to simplify matters) just as I did in the paper on "Longitudinal Stability," which I published in the AËRONAUTICAL JOURNAL for January, 1910. As Professor Bryan in reviewing my paper in *Nature* seemed to think that neglect of this variation might be unsafe, I should like the lecturer to give us his views on the subject. Personally, I think it is safe to omit the variation, and as it greatly simplifies the equation, the question might with advantage be further considered.

Rotary Derivatives.—In my paper, above quoted, I omitted these, because their effect must be very small—since they vary approximately as $\left(\frac{d\theta}{dt}\right)^2$,—and also because any effect they produce is to damp down the oscillations. As their inclusion considerably complicates the equations, and we are on the safe side if they are neglected, it seems better to drop them until it is shown that they really have an appreciable effect.

Fins, bent up edges, &c.—As regards these I have nothing to say against the theory proposed by the lecturer. I want, however, to point out that all such adjuncts are only required because the present-day aeroplanes have *rigid* surfaces. If such surfaces were constructed more on the lines of birds' wings it would not be necessary to have fins, &c., at all, as any effect produced by them is much better obtained from the flexible give-and-take wing design of Nature's flying creatures. It is much more satisfactory to start with a good type of surface than to try and make an indifferent one stable, and I do not myself believe that reliable machines will be constructed until this important improvement is adopted.

Simplification of system employed.—The only other point I would like to draw attention to is the necessity for producing an, at all events, comparatively simple system of investigating the "Stability" question. No one believes more in mathematical analysis of problems of this type than I do, but it is essential that the results obtained should be put before the aeronautical engineer in the simplest possible way, and that only items of real importance should be included in the theory developed from such analysis.

MR. ARCHIBALD R. LOW : As the first Member of the Society actively engaged in the practice of aviation to take part in the discussion, I might say that I came down to the meeting expecting to find a few enthusiasts prepared to discuss in quiet the matter—somewhat recondite from the design room—of Mr. Harper's paper.

It is refreshing to find instead this brilliant gathering, many bearing names of the highest standing on the scientific calendar, and backed by a solid array of designers, constructors and pilots, anxious and willing to bear their share in the great and vital work of co-ordinating scientific methods and results with workshop and flying ground practice.

My chief object in contributing to the debate is to emphasise the fact that Mr. Harper and Professor Bryan have completed a *method* of attacking the highly complex group of questions falling under the title of aeroplane stability.

They have, so to speak, perfected an analytical machine in the simplest form that will cover the whole range of these phenomena. Into this machine they have to put functional expression for the functions X Y Z L M N.

Having done so a turn of the analytical handle gives the characteristic determinantal equation and a further turn the quartic equation for the roots which satisfy it.

At present the expressions for X Y Z L M N necessarily take the form of empirical equations. If these empirical equations really follow closely the actual physically existing forces and couples in their numerical values, the whole problem of the conditions of stability (for small displacements at least) is reduced to the solution of a quartic equation.

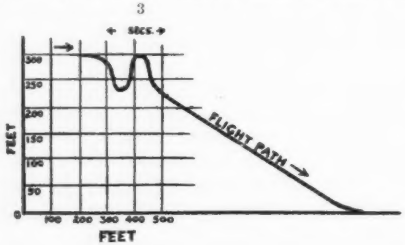
Mathematicians and engineers alike must be cautioned against accepting any conclusion arrived at by this mathematical method unless it has been repeatedly checked at every point. For while the user might not be aware of the significance of the simplifying assumptions made as to the form of the functions X Y Z L M N, and might forget the nature of the simplification, the mathematical machine could not, in its mechanical nature, but allow the full implication to appear in the result, however startling or contrary to experience. For instance, in Professor Bryan's book is published the result, that if the tangential reaction on the planes is negligible the distance of the centre of gravity from the supporting surfaces is indifferent, and this he exalts (somewhat out of proportion to its value) into a " Principle."

Now not only are these tangential forces important, amounting to something like one-tenth of the weight, and one half of the motor traction, but the surfaces have inertia and increase the principal moments of inertia of the aeroplane if they are more widely spaced.

Again, the conclusion that a high propeller thrust relatively to the centre of gravity aids recovery from an upward inclination is based on the assumption of uniform thrust. But if the motor stops or is cut off—two very common conditions—the force of inertia, equal at first to the propeller thrust. acts through the centre of gravity and sets up a couple increasing the tilt.

But these remarks must not be taken as criticisms of Professor Bryan's *method*, which is the only possible one.

For large displacements the mathematical work is bound to become much more severe. I have seen the late Astley on a 50 Gnome Bleriot monoplane carry through—unintentionally, of course—the extraordinary series of manœuvres indicated in the sketch roughly to scale—the pilot being thrown from his seat and landing astride the



fuselage. It is clear that the periodical linear and angular displacements from a state of uniform non-rotational velocity in a straight line were very large indeed, the angular variation being of the order of from —80° to + 80°, a total of 160°, the vertical displace-

ments of the order of —60 feet and back to the original level. Yet the machine retained sufficient "controllability" to recover and descend safely to earth in a glide. It is obviously of importance to know beforehand what limits, if any, there are to the power of recovery.

From the point of view of Mr. Harper's analysis, so far from distinguishing between "controllability" under the pilot's manœuvring, and so-called "inherent stability," we should regard these manœuvres as merely enabling the pilot (by muscular sensation, of course, and after long practice) to alter arbitrarily within certain determinable limits the functions L M N. A good and experienced pilot will be able so to manœuvre that the minimum possible displacements and rotations (about the moving axes) will occur. He will get the maximum damping effect in a similar way when the machine is forced to pitch or roll by atmospheric conditions.

A poor pilot will be unable to prevent a rolling or a serpentine progress under the same conditions.

At present the great need is an experimental determination of the "derivatives," X_u X_v L_u L_v, &c.

Certain valuable data might be obtained by observations of the oscillation of a model about a fixed transverse axis at an angle less than 90° with the direction of the air current. The Research Committee of the Society could profitably direct a great deal of such work.

In conclusion, the work done by Professor Bryan and Mr. Harper is of fundamental importance to the development of rational design as distinct from rule of thumb methods.

Mr. L. Bairstow: In considering the applications of mathematics to the problems of aeroplane stability, it is necessary to make certain assumptions which limit the generality of the problem. Some of the limitations are more apparent than real, and in the general survey of the subject as given in the paper before us it is possible that one assumption at least, although necessary for the rigid mathematical treatment which follows, is nevertheless almost unnecessary in considering the results. I refer to the necessity for assuming infinitely small disturbances from the flight path. In the case of the motion of a simple pendulum a similar assumption is necessary when forming the differential equation, but the solution, when obtained, can be applied to oscillations of finite magnitude, without sacrificing any great proportion of the accuracy. If this should be the case, the immediate result will be to enhance the value of results which are already of considerable importance.

A somewhat similar query arises from the discussion of "rotary derivatives." Are these of primary importance, and can Mr. Harper indicate the general effect on the conditions of stability? The importance of a knowledge of this effect arises largely from the state of the science of aeronautics, in which there is so much to be learnt; the order of attacking given problems is governed largely by what appears to be their relative importance.

Mr. A. E. Berriman: The Chairman has summed up the situation in his remarks on the necessity of wind tunnel experiments: as Mr. Low has also remarked, it is necessary to put the proper ingredients into the "mathematical machine" in order to obtain the desired results.

Mr. Harper's paper is not less interesting on account of its limitations, however, for if we understand the result and remember the hypotheses we at least acquire a recognisable point of view. To facilitate my own understanding of the subject I desire to put a few questions to the author.

Longitudinal Stability

1. The equation of longitudinal stability involves the factor d in the numerator. d is the wing loading.

2. From a remark made later to the effect that higher speed is the preferable method of increasing the stabilising value due to d, I should like to ask whether it is high wing loading in relation to speed that is implied by d, or just wing loading in the absolute.

3. It is stated that longitudinal stability is decreased during ascent; would the decrease be appreciable in a machine climbing five feet per second at 50 feet per second virtual horizontal velocity ?

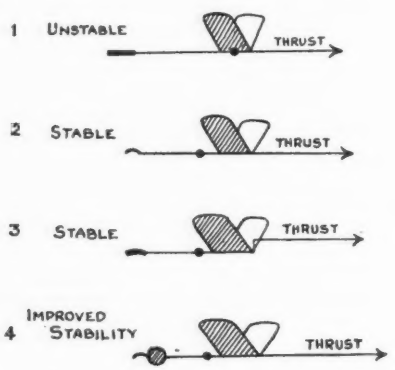
Lateral Stability

4. Turning to the section devoted to lateral stability, Mr. Harper virtually sums up the situation for still air by saying that vertical fins are necessary, and that any modified arrangement of the wings for the purpose of stabilising the machine does in effect create an equivalent fin in a definite position on the plane of symmetry, which is the vertical plane containing the longitudinal axis.

5. For instance, dihedral wings are equivalent to a vertical fin located above the shoulder.

6. I will ask Mr. Harper to say whether the following sketches sum up the situation as to the dihedral in still air.

THE DIHEDRAL IN STILL AIR



7. With reference to diagram 4, it would be interesting to know whether the rudder, as ordinarily employed, is of the area and in the position to satisfy the condition of the tail fin.

8. If not, is there any apparent reason why the rudder should not be designed to satisfy the conditions of steering and also those of a tail fin ?

9. In the paragraph relating to stabilisers, it appears that the wing tips may potentially serve in this capacity.

They form an equivalent fin at the point of intersection of lines drawn at right angles to them.

For stability, it is necessary that the tips should be upturned, which places their equivalent fin above the centre of gravity.

It is preferable that they should have a negative angle of incidence in order that their equivalent fin should be in front of the centre of gravity.

It is desirable that they should be retreated in order that their equivalent fin may not be too far in front of the centre of gravity and also because their value is enhanced by the greater distance between their equivalent fin and themselves.

These are the conditions for stability in still air. It is therefore inevitable that a gust will cant a stabilised aeroplane so designed, if we define a gust as a sudden veering of the wind.

If, therefore, it happened to be desired to neutralise the effect of a gust on a machine, it would seem reasonable to reverse the above conditions for still air stability.

10. Thus, it would seem proper to replace the up-turned tips by down-turned tips, thus bringing the equivalent fin beneath the centre of gravity.

11. A negative angle of incidence on a down-turned tip would place the equivalent fin behind the centre of gravity, *i.e.*, would project a virtual tail fin.

12. If the tips were also retreated, this equivalent tail fin would be still further behind the centre of gravity.

13. In the Dunne aeroplane, the wings are retreated, their tips are down-turned, notably in the monoplane, and have a negative angle of incidence. Apparently they represent, according to the theory, an equivalent fin as above.

14. Finally, I turn to another aspect of the problem that I regard as important—the fin effect of the wings on the damping of the initial disturbance caused by a gust.

It is, I think, of some practical value to make the canting of the machine under a gust sluggish, so that it will resist violent movements.

If the wing tip is depressed about a foot in one second while the machine is travelling at 50 miles an hour or so, the effective angle of incidence is appreciably increased while the movement continues.

The descending wing thus experiences an increased lift, while the rising wing experiences a reduced lift.

These forces will check canting, but they will not restore balance, to do which the pilot must warp.

Owing, presumably, to the lateral displacement of the centre of pressure towards the weather side of the machine, it is the lee wing that is depressed by a gust. I should like to ask Mr. Harper if he has investigated the relationship of the disturbing force to the damping force under such conditions.

15. The wings in this respect presumably act like the keel of a yacht. Regarded as fins, they should be very effective owing to their large size.

If this is the principal steadying factor in flight, then all aeroplanes have the quality more or less in common.

More when the wings are large, *i.e.*, lightly loaded, and more when they fly fast.

As the above conclusion favours light loading and is apparently opposed to the result relating to the factor d in the previously mentioned equation, I venture to suggest that this question of wing loading is worthy of further consideration from the above mentioned point of view.

Mr. Handley Page: The fundamental equations with which Mr. Harper starts are the simple statements that :—

(1) The propeller thrust must equal the resistance of the machine to motion.

(2) The lift on the machine is equal to the weight carried.

(3) The centre of head-resistance and propeller thrust must be coincident.

By developing these equations Mr. Harper obtains expressions in which we have in each case the stabilising force that is set up owing to the motion that ensues under a wind gust, and also the damping factor that is obtained to wipe out any oscillations that are set up. In general one finds that for a stable machine, that is, one that is unaffected by wind gust, the moment of inertia around the axis considered must be as small as possible and the righting force large. In Mr. Harper's equations the best values of tail or fin area and the distance between the main planes and the tail or fin area are found mathematically by making certain assumptions which involve the knowledge of a large number of coefficients. These coefficients can only be found experimentally after the particular machine has been designed and will be dependent upon the construction and details. It would seem, therefore, at the present state of our knowledge this method would be of most use in analysing and comparing the stability qualities of different types of machines, but would not be of great practical use in designing the machine. It would seem to be quicker if a model of the machine to be used were tested in a wind tunnel with varying lengths between fin and tail area and varying tail areas, so that stabilising factors could be calculated. In this way one would obtain a complete set of

data for different types of machines, and thus would obtain a general idea as to the stability of particular types of machines.

The theory detailed by Mr. Harper is developed for a plane of large aspect ratio, and movement of the centre of pressure on the main plane is supposed to be taken as negligible as regards the movement of the resultant centre of pressure of the whole system. I should like to ask Mr. Harper, whether the difference is appreciable and affects the result if an ordinary aspect ratio of, say, six to one is used and the plane curvature is such that the centre of pressure may move backward, say, a distance of one-fifth of the chord, with a variation of incidence angle from, say, 10° to 0°.

The stability problem with tail fin and either a turned-up tip or a fin placed above the main plane is of special interest to me. Some years ago, when experimenting with model gliders with a view to obtaining qualitative results as to stability comparisons of different model types, I found that taking a plane with ordinary square ends and fins of approximately correct proportions—one above the planes and the other at the tail—I did not obtain such good effects in high winds as with the turned-up tips and the swept-back plan form, as I could never obtain quite as good balance as with retreated wing tips. Perhaps Mr. Harper could give us some further opinions on the question of plan form.

Mr. T. W. K. Clarke: As Mr. Harper has pointed out, with all work and calculation of this kind there must, in order to simplify the initial labour, be a number of assumptions, and then, in order to use the results so obtained for practical purposes, certain corrections must be introduced. For instance, initially it is assumed that the supporting surfaces are narrow and flat and follow the sine law, also that the actions and forces on a simple machine consisting, say, of a main surface and a neutral tail may be obtained by considering each of these surfaces as being unaffected by the other. Such an assumption may give quite a wrong result. It is certainly pointed out in Professor Bryan's book that a correction is necessary for the wash effect from the front surface, and also Lanchester is quoted as showing that this correction may be very considerable and even variable.

For another instance, Mr. Harper, when dealing with the transverse stability of straight planes, *i.e.*, those having no dihedral angle, said "Straight planes alone cannot give stability; in fact, they cannot damp out a velocity perpendicular to the plane of symmetry nor right a cant."

But this we know is not so—the "sideways sliding motion of a straight plane" displaces the centre of pressure towards the lower tip and produces a righting motion. The correction for this with our present-day knowledge would be very hard to introduce.

The question then arises: if so many corrections are necessary, the values of many of which are very indefinite or unknown, are the results—though obtained, as they obviously are, at the cost of a vast amount of time and labour and the employment of most beautiful mathematical analysis—are these results of practical use? I think they are of some considerable value, but chiefly for the sake of comparisons, and as a guide. For exact results the various quantities and coefficients are not yet known with sufficient accuracy.

But such quantities as the resistance derivatives, rotary derivatives, wash effects, righting effects of planes—straight or otherwise—and various others are nearly all amenable to experimental research; in fact, the Research Committee of this Society has suggested that research on some of these lines should be carried out by its Members as soon as possible, and our Chairman has pointed out that some of this work is actually being done at the National Physical Laboratory, so that in the not distant future the theory Mr. Harper has explained to-night will be of the greatest possible use.

Mr. Harper has not given us any actual examples, which would, I think, have been interesting.

I have roughly applied his formula for the modulus of decay (on page 15) to the case of a machine in which:—

$\mu = \frac{1}{10}$ (drift to lift for main surfaces).
$f = \frac{1}{6}$ (drift to lift the machine as a whole).
$l = 20'$ (between centre of main surface and tail).
k (radius of gyration) $= 4'$ or $\frac{1}{5}$ of l.
$\frac{\sigma}{s} = \frac{1}{15}$ (ratio of tail to main surface).
$u = 80$ feet per second.

The expression for λ' then becomes $\lambda' = \frac{1}{100} \cos \theta - \frac{1}{10} \sin \theta$ where θ is the upward inclination of the flight path. For horizontal flight this gives $\lambda' = \frac{1}{100}$ approx., whence we find that in each second the amplitude of the longitudinal oscillation is reduced about two per cent., which indicates a very small amount of stability, also when the angle of ascent is 6° it disappears altogether, *i.e.*, any pitching motion is not naturally damped out. Using the formula for the damping of the transverse rolling I made out that in one second the rate of rolling is reduced to $\frac{1}{25}$ of its original rate, a very high rate of damping.

Dealing with some of the more general results Mr. Harper has given us, or such as are to be found in Professor Bryan's book (omitting all mention of fins, on which others have spoken), we note that :—

(1) Increase of head resistance gives increased stability (this applies both to the surfaces themselves and to the machine as a whole).

(2) Increase of speed gives increased stability.

(3) Increasing the angle of descent gives increased stability.

(4) Increasing the upward inclination of the thrust of the propeller up to a certain angle (2α) decreases the stability.

As regards No. 4 it is of interest to note that this angle which gives minimum stability is, as I pointed out some years ago, the angle which gives the maximum efficiency for the propeller.

Now from these we see that every characteristic that makes for aerodynamical efficiency, unfortunately makes for instability, so that in the future, when resistances will be reduced to a minimum, and efficiency to a maximum, if we want increased stability we must get it by increasing the speed.

But now we come to the crux of the whole question—do we want increased stability in this sense ?

If a machine is stable in calm air it has often been shown that it must be unstable or rather tossed about in rough air, and on the principle that " prevention is better than cure " it would apparently be better to make the machine as unaffected by gusts as possible, *i.e.*, to give it neutral stability.

But even here Mr. Harper's work would apparently show us that mathematically what we want is that each of the four roots of the characteristic biquadratic for λ should be zero or as small as possible, *i.e.*, that those expressions in Professor Bryan's book denoted by the old English letters B C D E should each be zero, or at least very small, and in this latter case the further expression H should be positive.

Further work in this direction might be instructive.

THE CHAIRMAN : We shall look forward with great interest to Mr. Harper's reply to the very interesting discussion that we have had, but you will no doubt agree that it is impossible at this late hour for him to reply at once to the large number of questions which have been asked. His reply will therefore appear in the AËRONAUTICAL JOURNAL subsequently.*

I have now much pleasure in asking you to pass a very hearty vote of thanks to Mr. Harper for his kindness in reading the paper which we have all heard with so much pleasure this evening.

On the proposition of Col. Fullerton, a very hearty vote of thanks to the Chairman for presiding was carried unanimously, and the meeting terminated.

* In the April issue.—ED.

AEROPLANES IN THE LIGHT OF THE MILITARY TRIALS

REPLY TO DISCUSSION

BY A. E. BERRIMAN, A.F.AË.S.

In eliciting so much that is really valuable from others, my own indifferent contribution has at least served some useful purpose. I shall, in particular, study Mr. Archibald Low's résumé of the French method of analysis with much indebtedness to him for putting it into suitable form for assimilation.

The criticisms on my remarks I recognise as exceedingly just, each from its own standpoint. Mr. Mervyn O'Gorman, for instance, is especially concerned with the scientific refinement of the practical aeroplane, by a process of full-scale research. A process of thought such as I have put forward would be diametrically opposed to that which he necessarily follows in his own work. All the more, therefore, do I appreciate his kindly comment.

My object, as Mr. Low remarks, has in part been to try to " expose in a simple way, to the layman, engineering quantities which are in themselves and in their relations highly complex." Inevitably, this has led to the elimination of many factors to which the engineer necessarily clings, but which confuse the issue to the lay mind. Aviation, while necessarily the business of the engineer, is a subject with technical aspects in which the layman has, so to speak, a traditional right of interest, particularly in this Society, which aims at encouraging such thought. To that side of the question I have therefore directed my endeavours.

Setting up a hypothetical machine, I have had in mind to emphasise the consequence of assuming an increase or decrease in the speed of flight on the part of an aeroplane with a given engine working at full power all the time.

I have observed that the lay mind—also the technical occasionally—tends to acquire a habit of referring to speed as if it involved no fundamental laws such as those that limit one horse-power to 375 mile pounds per hour and make the pressure on given wings at a given angle proportional to the square of the velocity.

If, for example, one horse-power is expected to effect in an object a level speed of 150 miles per hour against a resistance gradient of 1 in 6, it is evident that the weight must not exceed $\frac{375 \times 6}{150} = 15$ lbs. Thus, if it is assumed that the resistance of a hypothetical aeroplane at 150 miles per hour is one-sixth of its weight, it must be provided with one effective horse-power at the propeller for every 15 lbs. weight. This is only elementary mechanics, of course, but it is the simple mechanics of the aeroplane that the lay mind too often ignores.

Expressed graphically, the above relationship of constant power output against a constant resistance coefficient may be shown by a curve of V^{-1} on a chart of weight and velocity. In general terms such a graph says the faster you fly the less you must weigh, per unit of power. Alternatively, if the machine does not weigh less it must offer less resistance per unit of weight.

Now as to the wings. Assuming a constant angle, the pressure per unit of area increases as the square of the speed ; consequently, the area required decreases in like ratio for a given total weight to be supported. Graphically the relationship is shown by a V^2 curve on the previous chart.

Conversely, a given loading corresponds to a certain speed, which I call x to avoid confusion with the real speed of the machine.

At that speed a given load per horse-power, flying against a given resistance coefficient, needs a certain amount of power, which may be represented as a percentage of the unit power available. That percentage I call ε. Since x is proportional to $\sqrt{W_2}$ where W_2 is the loading, then ε is proportional to $W_1 \sqrt{W_2}$, which is the product of the weight and the square root of the loading. In the chart showing $W_1 \propto V^{-1}$ and $W_2 \propto V^2$, the speed is everywhere proportional to $W_1 W_2$.

It must, of course, be clearly recognised that x assumes a constant angle and the same wing section. It should be self-evident, therefore, that the method is merely related to a hypothetical case. The question arises, does it serve a useful purpose to establish such an hypothesis, aside from its positive use as an elementary exercise in mathematics. Perhaps not, but having regard to the general character of wing sections that have been tested, which seem to give a limit to the pressure at the critical angle in an order of .65 $c\rho V^2$ (which may be roughly expressed as $V^2 \div 300$ for flight near the ground) it seems not without interest, for instance, to compare their normal loading with the maximum possible at the same speed, by the aid of a chart on the lines suggested. The relationship, it seems to me, is related to the range of control.

CORRESPONDENCE

To the Editor of the AËRONAUTICAL JOURNAL

ARMY AEROPLANE TRIALS

SIR,—Now that Mr. Berriman's paper is in print it is possible to comment on it more systematically than was possible at short notice at the Meeting itself.

It will be noticed that he has at his disposal only equations (3), (5), (6), (7), p. 242. He might have written these in the more usual form

$$\text{Total weight } Z = K_y S V^2 = c_y^2 \qquad (5) \text{ and } (3)$$

$$\text{Motor horse-power } x = K_x S V^2 \div 75\rho \qquad (6)$$

$$\text{Surface } S = y^2 \qquad (7)$$

$$\text{whence } W_1 = \frac{Z}{x} = \frac{75\ K_y}{K_x} \times \frac{1}{V}$$

$$W_2 = \frac{Z}{S} = K_y V^2$$

$$\text{“x”} = W_1 W_2 = \frac{Z^2}{xS} = \frac{75\rho K_y^2}{K_x} V$$

$$\text{His “k” is } \frac{75\rho K_y^2}{K_x}$$

The dimensions of 75 and ρ are zero as both are numerical ratios.

$$\text{The dimensions of } K_x \text{ and } K_y \text{ are } \frac{\text{Weight}}{\text{Surface} \times \text{velocity square}}$$

$$= \left(\frac{mlt^{-2}}{l^2 \times l^2 t^{-2}} \right) = \left(\frac{m}{l^3} \right) = \text{density.}$$

Hence the dimensions of k are also that of density, so that $X = kV$ has the dimensions of density and velocity $= (ml^{-3} \times lt^{-1}) = (ml^{-2}t^{-1})$
not of density × hyperacceleration as the writer incorrectly stated on page 240.

$$\text{His } W_2 = f V^{-1} = \left(\frac{75\rho}{K_x} \frac{K_y}{V} \frac{1}{V} \right)$$

$$W_2 = fV^2 = (K_y V^2)$$

$$\therefore\ W_1 W_2 = f V^{-1} f V^2 = f V$$

remind one of the late Professor Chrystal's Banker, whose conception of functionality was found on examination to be limited to that of simple proportionality.

Owing to the absence of the equations (1) and (2), page 241, Mr. Berriman's hypothetical aeroplane, when it varies, does so without regard for its factors of safety, and the limits imposed thereby on practical designers, while the absence of equations (4), (13) and (14), page 242, leave him groping in the dark as to the direction in which to look for the best dimensions and best horse-power with the motors, materials, and methods of design at his disposal, and with the factors of safety permissible.

A. R. LOW.

To the Editor of the AËRONAUTICAL JOURNAL.

SIR,—Kindly print the following list of *errata* in the writer's "Note on Theory of Aeroplane Dimensions," October, 1912 :—

Page 241 : Eqns. (3) and (5) for "z" read "Z."
Footnote (1) for "Z_1" read "z_1"

Page 243 : Eqn. (17) for "z_{10}" read "Z_0" Eqn. (18) for "K_1" read "k_1" Eqn. (20) for "$Y_0{}^3$" read "$y_0{}^3$" for $\frac{1}{k_1{}^3}$ read $\frac{1}{k_2{}^3}$

Page 244 : Column 3 of table for "Z" read "z."

Page 245 : Line 6 to left-hand side of "z = etc." add the term "—400." Second paragraph, line 9, for "test gliding velocity" read "best gliding velocity."

Page 246 : Ante-penultimate par. This is an obvious misreading of equation 19. For "High specific glider weight" read "low specific motor weight." Even this correction is inadequate, for the high loading of the Bristol is also in part due to the high value of A^3, that is, of $K_y{}^3 \div K_x{}^2$.

A. R. LOW.

NEW BOOKS AND PUBLICATIONS

*GUIDE PRATIQUE D'AVIATION. Lieut. Sensever et Lieut. Péralda. Preface by Col. Hirschauer. Paris : Librairie Chapelot. 1912. pp. 201. Illus.

AERONAUTICAL ENGINES. A. Graham Clark. London : Institution of Automobile Engineers. 1912.

*LES HYDRAÉROPLANES. F. R. Petit. Paris : H. Dunod et E. Pinat. 1912. pp. 84. Illus. 3 francs.

*LES HYDRO-AÉROPLANES. Pierre Rivière. Preface by Alphonse Tellier. Paris : Librairie Aeronautique. 1912. pp. 88. Illus. 3 francs.

EN QUOI CONSISTE LA STABILITÉ. Alex. Sée. Paris : Gauthier-Villars. 1913. pp. 35. Figs.

LES TURBINES À GAZ. L. Ventou-Duclaux. Paris : H. Dunod et E. Pinat. 1912. pp. 128. Figs. 3 francs 75.

INSTRUCTIONS MÉTÉOROLOGIQUES. (5th edition). A. Angot. Paris : Gauthier-Villars. 1911. pp. 161. Figs.

AÉRO-MANUEL, 1912-13. Ch. Faroux et Et. Bernard. Paris : Dunod et Pinat, 1912. pp. 550. Figs. 10 francs.

TH. SCHEIMPFLUGS LANDVERMESSUNG AUS DER LUFT. G. Kammerer.

BULLETIN DE L'INSTITUT AÉRODYNAMIQUE DE KOUTCHINO. (Fascicule IV.) Moscou : I. N. Kouchnéreff et Cie. 1912. pp. 140. Figs.

ABRÉGÉ SUR L'HÉLICE ET LA RÉSISTANCE DE L'AIR. Maurice Gandillot. Paris : Gauthier-Villars. 1912. pp. 188. Figs. 8s.

DIE ARBEITEN DES KÖNIGL. PREUZISCHEN AERONAUTISCHEN OBSERVATORIUMS BEI LINDENBERG IM JAHRE 1911. Dr. Richard Assmann. Braunschweig : Friedr. Vieweg und Sohn. 1912. pp. 287. Figs. 15 Mark.

* Review appears in this issue.

LIST OF FATALITIES

Date. 1912.	Name.	Nationality.	Machine.	Place.
Nov. 30 ..	P. Arrondel	French	(1)	Juvisy
Dec. 15 ..	Lieut. W. Parke, R.N. A. Arkell Hardwick(P.)	English	Handley-Page (1)	Wembley
Dec. 19 ..	Horace Kearney Chester Lawrence (P.)	American	Kearney hydro-aeroplane	Drowned (near Rodondo)
Dec. 21 ..	Lieut. Dransfeld	German	(1)	Mayence
Dec. 24 ..	Ed. Petre	English	Martin-Handasyde (1)	Marske-by-Sea
Dec. 24 ..	Fung-Zue	Chinese	——	Pekin
1913.				
Jan. 1*..	Lieut. Berode	French	(2)	Remiremont
Jan. 3 ..	Mons. Mallet (P.)	French	Nieuport hydro-aeroplane	Fécamp
Jan. 13 ..	L. S. Macdonald H. England (P.)	English	Vickers (2)	Drowned (near Dartford)
Jan. 19 ..	Lieut. Origone	German	Blériot (1)	Brandzen
Jan. 23 ..	Frank Boland	?		Port of Spain (Trinidad)
Jan. 23 ..	Lieut. Schlegel	German	Mars (2)	near Magdeburg
Jan. 24 ..	Ch. Nieuport (P.) René Guyot	French	Nieuport (1)	Méréville
Jan. 28 ..	M. Eusebione	S. American		Villa Lugano
Jan. 29 ..	Herr Palz	German		Bränderheide

* Date of death. Accident Dec. 31. Struck by propeller while descending from the machine.

(P) Passenger. (1) Monoplane. (2) Biplane.

REVIEWS

Cours d'Aeronautique. (Part III.) By M. Marchis. (Paris: MM. Dunod et Pinat 1912. pp. 279. Illus. Price 12 francs.)

THIS is a most interesting and complete study of aeronautical work designed to suit the needs of aeronautical students at the University of Paris. There is a complete study of the spherical balloon as regards lifting capacity, strength necessary, etc.

In the aeroplane portion of the course all the available experimental results are very ably collected—the Eiffel, Göttingen, and Riabouchinsky results being all set out and diagrams illustrating them presented very clearly. The whole forms an admirable collection of various workers' results.

F. H. P.

Guide Pratique d'Aviation. By Lieuts. Sensever and Péralda. With a preface by Col. Hirschauer. (Paris: Chapelot, 1912. pp. 204. Price 2 francs 50.)

WRITTEN by two practical aviators, this book is an outstanding example of how well they do these things in France. Every flying pupil should read it, and even the veteran, if he will so condescend, will find many a useful hint in its pages. The six parts into which it is divided consist of (i.) Preliminary Remarks, dealing with the physical and moral qualities of an aviator, his clothes and such like; (ii.) Pupilage; (iii.) Advanced Flying; (iv.) Elementary Theory (this is a very good chapter); (v.) Some Problems, i.e., stability, speed, height, and hints on motors; (vi.) Military Questions—a sound chapter of much merit. The appendices, four in number, give directions for swinging an aeroplane compass, notes on cloud forms and metacentric curves, and a small dictionary of terms.

One quotation of advice to aviators suffices to show the book's quality—"Be master of your nerves, and do not forget that the problem of the aviator, as Karl Marx has said of the social problem, is a question of digestion!"

T. O'B. H.

Das Flugzeug in Heer und Marine. By Olszewski und Helmrich von Elgott. (Berlin: Richard Carl Schmidt, 1912. pp. 288. Illus. 7 marks.)

THE above work is Volume VI. of Bibliothek für Luftschiffahrt und Flugtechnik, and purports to be a handbook dealing with the whole subject of flying for military purposes.

The authors are officers in the German Army, one being attached to a Prussian Field Artillery Regiment. The book is well written, the language is simple, and unnecessary technicalities are avoided.

Yet one must confess to a certain amount of disappointment after perusing the work. It is not up to date. However attractive it may be to the general reader, it has but limited utility to the service student for whom presumably it is partly intended.

The date of publication is 1912. The principal section of the book is that which deals with the French autumn manœuvres of 1910. Over 100 pages, i.e., nearly half the book, is taken up with the "history" of the military aviation corps in 25 countries. The first 50 pages are occupied with the history of the development of the aeroplane from the kite and the glider, and a short description of the main parts of the aeroplane. These first two sections could very well have been dispensed with. Naval aeronautics, on the other hand, is given but a section of a dozen pages.

Points treated in the section dealing with the military use of aircraft include: the use of aeroplanes in war as means of communication; transport; biplanes versus monoplanes; volunteer aeroplane corps; fighting aeroplanes; directional steering; observation problems and photography; aeroplanes and their use in sieges; aeroplanes versus airships.

The authors have inserted short biographies of 27 officers of all nationalities, who have lost their lives while flying.

In Section VIII. the strategical and tactical value of flying machines in the light of experiences derived from grand manœuvres is discussed.

On the whole, one may say that the book is rather of a "popular" character and suited to the semi-serious reader; it is hardly worth seven marks to the up-to-date disciplined student of aeronautics.

J. E. H.

Sovereignty over the Air. A Lecture delivered before the University of Oxford on October 26th, 1912, by Sir H. Erle Richards, K.C., K.C.S.I., B.C.L., M.A. Chichele Professor of International Law and Diplomacy, and Fellow of All Souls' College. (Oxford : Clarendon Press, 1912. pp. 27. 1s. 6d. net.)

READERS of Dr. J. F. Lycklama à Nijeholt's "Air Sovereignty" who are in agreement with the conclusions of that authority, arrived at in 1910, will welcome the well-reasoned and powerful arguments of Sir Henry Richards in favour of vesting the sovereignty of the air space in the Government of the subjacent country.

The lecturer treats first of peace conditions, and prefaces his discussion thereof by the clear presentation of the two conflicting views :—

1. Are Governments to have sovereignty over the space above their territories in the same way as they have sovereignty over the territories themselves? Are they to be able to regulate or forbid the user of that space as they will, subject only to such reciprocal obligations as they may bind themselves to perform by agreement? or

2. Is the air space to be free to all, like the high seas, subject, at the most, to a control restricted to certain specified purposes, and exercisable only within defined limits?

At the recent International Conference assembled in Paris on the invitation of the French Government, it was found impossible to come to an agreement on the fundamental question at issue, and until such agreement is arrived at no steps can be taken effectively, even by a majority of the Powers, to legislate on the subject; for a majority of States has no power to bind a minority. Sir Henry Richards boldly takes the view that State rights over the air "are already fixed and determined by admitted principles of international law, and that if convention be necessary, it is necessary only to give effect to those principles, in the regulation of aerial traffic from State to State." He considers that the question is conclusively settled by the fundamental principle of international law, that "Sovereign States are entitled to all those rights which are necessary for the preservation and protection of their territories": and points out that "the necessity for giving to States the control of the space above their territories is even more urgent and more obvious than it is with regard to the waters which wash their shores. If the air were free, the defensive works and military dispositions of every State would be exposed to the view of an air vessel above it. . . . Indeed, it is not too much to say that sovereignty over the land can never be made effective if the air be beyond the jurisdiction of the sovereign power." It is pointed out that such sovereignty has been tacitly assumed already by many States in connection with such matters as wireless telegraphy, and that our own Aerial Navigation Act of 1911 is a direct assertion of such sovereignty. Again, the right of the landowner to the air space above his land is recognised, and is, indeed, embodied in the Code Napoleon, in the codes of Germany, Switzerland, Italy, the Netherlands, Belgium, Spain, Portugal, Austria, Japan, Turkey, and the United States: the recognition of the rights of individual proprietors, '*usque ad cœlum*,' involves the assertion of State sovereignty to the same extent.

The lecturer disposes without difficulty of the argument that the air should be free, subject to certain limitations and exceptions.

This point of view was adopted by a majority at a meeting of the Institute of International Law in Madrid in 1911, when the navigation of the air was declared to be free, "subject to the rights of subjacent states to regulate aerial traffic in the interests of their own security and that of the inhabitants and their property." But, as Sir Henry Richards points out, "It seems certain that if any form of reservation were to be adopted, there would result an unending series of disputes as to the particular legislation passed by each State . . . no limited measure of control can enable States to adequately protect their territories. . . . It is far better from every point of view to admit that States have full sovereignty over their air spaces, and to trust to the desire for reciprocity and the general comity of nations to ensure sufficient facilities for aerial traffic."

The author then proceeds to discuss special considerations in regard to war, and shows how the arguments in favour of State sovereignty are strengthened in this connection, more especially when we consider the situation of neutral states, which would be placed in an intolerable position if the air space above their territory were free to the hostile air fleets, subject only to the power of the neutral State to compel them to keep clear. In considering the question of discharging bombs or projectiles from air vessels, the author is not quite conclusive; he quotes the Hague Declaration of 1899, prohibiting the discharge of projectiles from air vessels, which was in force for five years only, as none of the Powers, except Great Britain, the United States, and Austria-Hungary, were willing to renew it. He deprecates the horrors which must ensue from aerial warfare, but admits that no considerations such as these will cause nations to forgo the advantages which these new forms of warfare would gain for them; and finally dismisses this part of the subject as being scarcely germane to the main question, which is the sovereignty of the air. As, however, the question of the discharge of projectiles has been introduced,

it may be permitted to point out that the Declaration of the Hague Conference above mentioned was brought up for renewal in 1907 ; it was felt by many of the Powers that inasmuch as aerial vessels used for reconnaissance or for any other military purpose would certainly be attacked by every legitimate means, it was altogether unreasonable to deprive them of the means of retaliation; at the same time it was generally agreed that the use of projectiles and explosives by aerial vessels must be confined within the same limitations as govern their use by the land and sea forces, and accordingly Article 25 of Convention 4 was amended to read as follows :—" The attack or bombardment *by any means whatever,** of undefended towns, villages, dwellings, or buildings, is prohibited." It is well to emphasise this point, so that the atmosphere may be kept clear of the bogy of peaceful towns being bombarded or set on fire by hostile air vessels.

It is satisfactory to note that the eminent German jurist Professor Ernest Züelmann, in an essay entitled " Luftschiffährtsrecht " (Leipsic, 1910), takes the same view, and uses many of the same arguments as Sir Henry Richards. The more this subject is discussed by such authorities, the nearer shall we approach to obtaining an agreement between the Powers on the question of principle, after which regulations can be coded to govern practice both in peace and war.

F. G. S.

Les Moteurs à deux Temps. By L. Ventou-Duclaux. (Paris : H. Dunod et E Pinat, 1912. pp. 127. Illus. 4 francs 50.)

THE two-stroke cycle always forms an interesting mechanical problem, owing to the inherent nicety of design and adjustment required to ensure the expulsion of the burnt gases and the recharging with fresh combustible during the brief period afforded by a small fraction of one and the same upstroke of the motor piston.

The author throughout his work lays stress on the conflicting factors of maximum power and lowest fuel consumption : if we want maximum output we must sacrifice some portion of each fresh charge down the exhaust pipe.

The book is written in a clear and methodical way, and goes into much detail in making comparisons between the relative merits of two- and four-stroke engines : although obviously biassed in favour of the former, the author does not, however, fail in most instances to give due weight to certain disadvantages inseparable from the two-stroke cycle, as, for example, the thermal loss in preliminary compression of the charge to force it into the power cylinder.

In Chapter I. the principles of the subject are fully discussed, rather more from the practical point of view than from the standpoint of pure thermo-dynamical theory. In Chapter II. the author classifies two-stroke engines into two main types, i.e., those in which preliminary compression is effected :—

(1) By separate pump or by rotary blower (as in the English N.E.C. engine).

(2) By motor piston itself.

And he further subdivides class (2) into those motors where this compression is carried out :—

(A) In separate portion of motor cylinder ;

(B) In crank chamber ;

(C) In motor cylinder itself (the two-stroke Anzani engine appears to be the only representative of this type).

This portion of the work is perhaps the most interesting, though few of the 40 engines illustrated have been applied to aviation, and many of the remainder have not advanced beyond the experimental stage.

The author does not devote much space to the consideration of the requirements of aero-engines, but points out that the designers of aeroplane motors have hitherto followed two parallel tracks in endeavouring—

(1) To decrease weight for horsepower ;

(2) To secure more uniform torque ;

the latter being an essential condition for the best propeller efficiency, though it is necessarily antagonistic to requirement (1).

He emphasises the importance of examination of the exhaust gases, as the only means of rendering a true heat account. Analysis alone is able to show what proportion of combustible is evacuated in the exhaust. The illustrations are good, and the descriptions are easy to follow. The concluding Chapter (III.) contains a list of 246 French patents (since 1896) dealing with two-stroke engines.

It is somewhat surprising to find that on page 79 *et seq.* the author refers at length to the old idea of the stratification of the combustible charge, and supports his remarks by reference to Otto and others.

* The words in italics constitute the Amendment.

It was, however, shown many years ago by Dugald Clerk that the theory of stratification as first put forward by Otto is quite erroneous, and it is well known that under the conditions obtaining in the internal combustion engine cylinder such stratification cannot exist.

H. F. L.

Les Hydraeroplanes. By F. R. Petit. (Paris: Dunod and Pinat, 1912. pp. 82. Illus. 3 francs.)

Les Hydro-aeroplanes. By P. Rivière. (Paris: Librairie Aéronautique, 1913. pp. 88. Illus. 3 francs.)

It seems a great pity that the authors of these two books, which were published almost simultaneously, did not collaborate. As it is, the long-suffering public has to invest six francs instead of three. These are the first books published on the subject, and between them certainly do it pretty well. M. Petit is more thorough, because more scientific. His chapters on floats and on the stability and equilibrium of "hydraéroplanes"—as he calls them—are distinctly valuable. They constitute a firm starting-point; they are sign-posts indicating the right direction to the inquiring manufacturer.

The last half of the book is concerned with descriptions of various machines, well done, but lacking scale drawings, for which we must refer to M. Rivière. This latter gentleman has gone in for something more popular, and reprinted much of his contributions to *L'Aéro*. His chapter on floats makes very interesting reading, and the illustrations are exceptionally fine.

It is good to remember that hydroplanes and the stepped floats of hydro-aeroplanes originate with an Englishman, the Rev. C. M. Ramus, of Playden Rectory, Rye, Sussex. According to a Memorandum dated April 10th, 1872, and signed by the then Director of Naval Construction:—"Rev Mr. Ramus has to-day communicated to me the plan of designing steamships for great speed referred to in his letter of the 5th inst. It consists in forming the ship of two wedge-shaped bodies, one abaft the other. The object of the invention is to cause the ship to be lifted out of the water by the resistance of the fluid at high speeds. The double wedge provides that while the bow is lifted by the foremost of the inclined surfaces, the stern is lifted by the after one, and these may be so placed with regard to each other that the ship shall always keep her proper trim."

Everything in modern aeronautics was initiated in this country, and left to other countries to develop and to reap the benefit and the honour.

T. O'B. H.